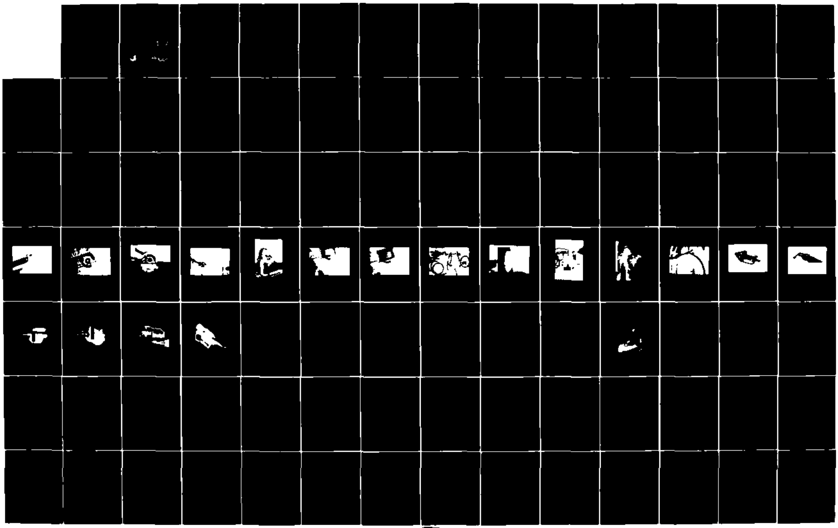
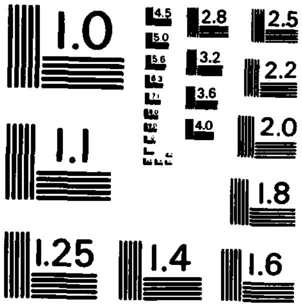
AD A124 308 DEVELOPMENT OF AN OPTIMUM RESCUE TOOL DETAILED PROTOTYPE CONCEPT DESIGN(U) AMETEK/ORED SANTA BARBARA CA R A OLSEN ET AL. JUN 81 AFESC/ESL-TR-81-28 1/2

UNCLASSIFIED F08635-80-C-0356 F/G 6/7 NL





MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

ESL-TR-81-28

(12)

DEVELOPMENT OF AN OPTIMUM RESCUE TOOL, DETAILED PROTOTYPE CONCEPT DESIGN

RALPH A. OLSEN
JOSEPH L. WALKER

AMETEK, OFFSHORE RESEARCH & ENGINEERING
DIVISION, 1224 COAST VILLAGE CIRCLE,
SANTA BARBARA, CA 93108

JUNE 1981

FINAL REPORT
SEPTEMBER 1980 - MAY 1981

AFESC

AIR FORCE ENGINEERING AND SERVICES CENTER

ENGINEERING & SERVICES LABORATORY
AIR FORCE ENGINEERING & SERVICES CENTER
TYNDALL AIR FORCE BASE, FLORIDA 32403

NOTICE

PLEASE DO NOT REQUEST COPIES OF THIS REPORT FROM HQ AFESC/RD (ENGINEERING AND SERVICES LABORATORY). ADDITONAL COPIES MAY BE PURCHASED FROM:

NATIONAL TECHNICAL INFORMATION SERVICE
5285 PORT ROYAL ROAD
SPRINGFIELD, VIRGINIA 22161

FEDERAL GOVERNMENT AGENCIES AND THEIR CONTRACTORS REGISTERED WITH DEFENSE TECHNICAL INFORMATION CENTER SHOULD DIRECT REQUESTS FOR COPIES OF THIS REPORT TO:

DEFENSE TECHNICAL INFORMATION CENTER
CAMERON STATION
ALEXANDRIA, VIRGINIA 22314

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER ESL-TR-81-28	2. GOVT ACCESSION NO. A124808	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) DEVELOPMENT OF AN OPTIMUM RESCUE TOOL, DETAILED PROTOTYPE CONCEPT DESIGN		5. TYPE OF REPORT & PERIOD COVERED Final Report Sep 80-May 81
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) RALPH A. OLSEN JOSEPH L. WALKER		8. CONTRACT OR GRANT NUMBER(s) F08635-80-C-0356
9. PERFORMING ORGANIZATION NAME AND ADDRESS AMETEK, Offshore Research & Engineering Division, 1224 Coast Village Circle, Santa Barbara, CA 93108		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS JON: 2505-1004 Program Element: 64708F
11. CONTROLLING OFFICE NAME AND ADDRESS HQ AFESC/RDCS, Tyndall AFB FL 32403		12. REPORT DATE June 1981
		13. NUMBER OF PAGES 155
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) UNCLASSIFIED
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

Availability of this document is specified on reverse cover.

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Fire fighter tools
Fire fighter rescuemen
Forcible entry
Crash firefighting
Fire fighting
Crash rescue

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report describes the detailed prototype concept design of a new single, multifunction, lightweight tool for use by fire fighting and rescue personnel in the rescue of personnel from damaged aircraft. Displacing and cutting functions are integrated into the new concept. The conceived tool has a spreader, shear, piercing, prying tip; and router type saw. The tool is powered pneumatically and has a friction/spark, prevention/containment system which includes a spark minimizing cutting tool configuration, a spark entrapment barrier around the cutting tool, and an extinguishing/suppression agent system for flooding the

over

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

cutting surface and surrounding zones. Concept drawings, specifications and developmental tests are included along with leading references on spark and flammability technology.

PREFACE

This final report was prepared by the Offshore Research And Engineering Division, Ametek, Santa Barbara, California, under Contract Number FO 8635-80-C-0356 with the Air Force Engineering And Services Center (AFESC), Tyndall Air Force Base, Florida 32403. Work was begun in September, 1980, and completed in May, 1981.

This report sets forth a prototype concept design for the optimum aircraft rescue tool that would integrate the most desirable features of several tools. Appendix A of this report contains a state-of-the-art study of rescue tools classified by displacing and cutting function. AFESC project officer was Captain Anthony J. Kwan.

An effort was made to assure complete coverage of all domestic rescue tools and manufacturers in this study. All normal catalog and reference sources were reviewed. Exclusion of any tool or manufacturer was unintentional. Mention of a specific product does not constitute either endorsement or rejection by Ametek Offshore Research and Engineering Division or the Department of the Air Force. Use for publicity or advertising purposes of information from this publication concerning proprietary products is not authorized.

This report has been reviewed by the Public Affairs office (PA) and is releasable to the National Technical Information Service. At NTIS, it will be available to the general public, including foreign nations.

This Technical Report has been reviewed and is approved for publication.

Anthony J. Kwan

ANTHONY J. KWAN, Capt, USAF
Project Officer

John E. Goin

JOHN E. GOIN, Lt Col, USAF
Chief, Engineering Research Div

Francis B. Crowley III

FRANCIS B. CROWLEY III, Col, USAF
Dir, Engineering & Services Lab

(The reverse of this page is blank)

TABLE OF CONTENTS

TABLE OF CONTENTS (CON'T)

LIST OF FIGURES

LIST OF FIGURES (CON'T)

SECTION I

INTRODUCTION AND SUMMARY

1.1 BACKGROUND

The Air Force has long been committed to the conception, development, and introduction of new methods and equipment to improve aircraft performance and operation, and to further improve individual working conditions and safety. These commitments extend to overall operational readiness, systems reliability and maintainability, and cost effectiveness, which are vital to the Air Force goals. Major pioneering efforts have contributed over the years to this continuing goal for improvement. The improvements have been accomplished despite budgetary and inflationary pressures, and personnel retention limitations. Development of an optimum rescue tool has been undertaken, within the context of the Air Force goal of continuing improvement.

1.2 RESCUE TOOL REQUIREMENTS

A wide range of tools with a diversity of functions, sizes, and capacities currently is used to rescue personnel from damaged aircraft. Appendix A of this report, entitled "State-of-the-Art Survey," summarizes the principal tools now available. Tool functions include spreading, cutting, sawing, prying, shearing, chiseling, wedging, pulling, lifting, drilling and piercing.

The assortment of rescue tools now available for use in forcible entry includes pry axes, gas driven saws, etc. Each tool has a place in the overall rescue scheme, but each is deficient in forceful entry and extrication of trapped pe sonnel. Examples of deficiencies are:

- Gas-powered saws produce sparks when cutting metal and generate high temperatures from friction.

- Hydraulically operated tools powered by gasoline engines are awkward to handle and too bulky for use by rescue personnel inside aircraft.

- Hand tools for prying doors cannot penetrate hardened metal structures of aircraft.

A large number of tools are transported to the scene of a crashed aircraft. Valuable time is lost deciding which tool to use, and several trips to and from the aircraft and rescue vehicle are required.

In a specific rescue operation, it is usually necessary for rescue personnel to select and use several tools, most of which are single or common functional tools, to accomplish the rescue. For example, a cutting tool may be selected to create a small opening or point of entry. Then a spreading tool may be selected to enlarge that opening. Each tool may be heavy and require additional pulling and support of lengthy supply hoses. Often, a hand-carried ladder is needed to climb to the best rescue access point. The multiple combinations of individual tools and their weight, bulky and restrictive supply hoses, and ladder access make the rescue task a demanding one. The risk of creating fire or an explosion from sparks or heat further complicates decisions made by rescue personnel selecting tools.

The Air Force and the Air Force Engineering and Services Center, Tyndall AFB have sought ways to improve effectiveness of rescue operations. Extensive tool and concept reviews were made and the project covered in this report was initiated.

1.3 SUMMARY OF DESIGN CONCEPT

A concept has been developed for a rescue tool to meet Air Force requirements. Risks were reviewed and assessed and the confidence in meeting requirements is high. This concept is described in the following paragraphs.

The single lightweight tool employs a pneumatically-actuated spreader or displacing device capable of exerting 4000 pounds of pressure through a 12-inch range of both spreading and closing. A pneumatically-operated cutting saw and a router-type penetrator/cutter are integrated into the tool to create openings. The cutters can create small openings for insertion of ejection ballistic hose cutters or spreader jaws, and larger holes in materials and structural shapes used in air frames, to permit egress of entrapped people.

The cutting saw and penetrator/cutter each operate within a unique splaying-type bristle barrier for containment of sparks. A halogenated extinguishing agent system (Halon 1211) is included to provide a supplemental protective cutting envelope. The Halon is contained within the tubular handle structures. Additional features are incorporated, including a piercing joint, jaw gripping serrations, and knife edges for shearing. A chipping tool option may also be included. Initial power is supplied from a hand-carried pneumatic reservoir, normally dropped on the ground near the foot of the access ladder or at the point of entry to the aircraft. The reservoir is designed to be charged by air compressor facilities already in place at air bases. A small diameter whip line, easily dragged from the drop point, connects the reservoir to the tool. Connection of replenishment air to keep the tool running on exhaustion of the initial ready service supply is made to the reservoir at the drop point. As described, the tool employs proven spreading and cutting components, a low spark potential cutting method, and is considered the lowest development cost approach to the optimum rescue tool.

An alternative concept was examined involving use of a higher cutting speed circular saw with a unique spark collection and management system. This concept also could be developed, but because of its greater weight, would require major special parts and result in substantially higher development costs to achieve performance and weight objectives.

Other alternatives examined include use of nitrogen or CO_2 as (1) the motive fluid for the spreader cylinder and cutter motors, and also (2) to create the fire protection envelope. Similarly, this approach was considered feasible, but would result in greater component and development costs to achieve objectives.

1.4 RECOMMENDATIONS

The recommendation was made to proceed with development of the rescue tool as described, with a Phase II Project to complete detail component design of the tool sufficient for prototype construction. Construction and testing would follow.

SECTION II
CONCEPT DESIGN

2.1 PERFORMANCE OBJECTIVES FOR OPTIMUM RESCUE TOOL

A set of performance objectives or initial design targets was developed for an optimum rescue tool. At minimum, the tool must satisfy the requirements listed below:

- Operating environment
  - must function in an aircraft crash environment where fuel vapors (NFPA Class I flammable liquids) are present without creating an explosion or fire hazard resulting from sparks, friction, or the power source.

- Ease of handling
  - total maximum weight of tool must not exceed 25 pounds.
  - must be compact to function effectively in the confined space of Air Force fighter and bomber type cockpits to free aircrew members from entanglement.

- Basic functions
  - must be capable of opening aircraft for ingress/egress of entrapped personnel by: (1) cutting skin, ribs and other aircraft components as necessary to gain entry, and cutting ballistic hoses on all types of aircraft egress systems; and (2) displacing aircraft hatches, canopies, and doors.

- Operating life
  - must operate continuously at 100-percent power for at least 3 hours without reservicing.
- Power source
  - The rescue unit will be designed as no more than two separate tools capable of simultaneous operation from the same power source.

    The power source will be included in the conceptual design. The contractor shall design the power source for installation on the A/S 32 P-10 vehicles. It will be capable of operating at least 3 hours at 100-percent power, have a 200-foot power-source-to-tool working range, and a gross weight not greater than 2000 pounds.
- Other objectives

  In addition to the objectives set forth in Contract F08635-80-C-0356 and listed above, the tool shall be cost effective, reliable, and readily maintainable. As a long range objective, the tool must be useful in structural rescue as well as aircraft rescue. However, since the aircraft rescue mission is paramount, specific considerations (such as increased weight) which could potentially facilitate structural rescue and also have potentially adverse implications to aircraft rescue will not be addressed in the initial design. Functional objectives will be directed to aircraft rescue only.

2.2 TECHNICAL APPROACH

The project was conducted in the general sequence shown (in simplified form) in Figure 1. Administrative and management functions, including progress reports, are not shown.

2.2.1 Initial Design Assumptions

Initial design assumptions were made to define a concept tool. In the initial AMETEK approach, an integrated tool was visualized with a gas powered saw and a gas powered spreader all in one body with common hand grips. Shearing and pulling features were also integrated into the spreader mechanism. Spark control and fire management was accomplished through use of an inert gas envelope containment for the saw. Either CO_2 or N_2 was visualized as the fluid for driving the cylinders and the fire protection envelope. Initial design assumptions became the base for functional analysis and the iterative design and redesign procedure which progressed throughout the project.

2.2.2 Analysis and Design Modification

This phase of the project included analysis and grouping of basic tool functions; a review of rescue instruction practices and the preferences of experienced instructors at the Air Force Rescue School, Chanute AFB; a detailed state-of-the-art survey; a review with Air Force Engineering and Services Center (AFESC) personnel at Tyndall AFB; and a review of other data, including technical literature. Modifications based on this analysis were then incorporated into the design.

2.2.2.1 Tool Functions. A detailed study of individual tool functions required for rescue operations identified two principal tool functions: displacing and cutting. Displacing involves pushing or pulling apart, and such traditional functions as spreading, prying, levering, and wedging. Cutting includes traditional functions of sawing, chiseling, axing, grinding,

piercing, shearing, and routing. Some cutting functions (sawing, grinding, routing) may involve metal removal and chip formation, where others involve separation without removal. The basic functions are diagrammed in Figure 2. Functional analysis confirmed inclusion of cutting and displacing functions in the initial design assumptions.

2 2.2.2. Rescue Instruction and Instructor Preferences, Chanute AFB. Experienced faculty at the Air Force Rescue School provided valuable advice and recommendations for tool features and capabilities. Included was a recommendation to utilize pneumatic systems whenever possible to ensure compatibility with existing air bottle and charging facilities at Air Force bases, and thereby minimize costs of introducing the new tool.

2.2.2.3 State-of-the-Art Survey. Results of this survey are contained in Appendix A of this report.

2.2.2.4 Review by Air Force Engineering and Services Center, Tyndall AFB. AFESC personnel reaffirmed the objectives defined in Contract F08635-80-0356, and the need for a better way to accomplish rapid rescue of entrapped personnel. The importance of aircraft rescue over structural rescue was emphasized.

2.2.2.5 Other review and analysis. Technology relating to spark formation and flammability potential was reviewed. The principal resource available from the literature is an article entitled "Friction Spark Ignition in Crash Fires," by the Lewis Flight Propulsion Laboratory of NACA (NASA) 1957. It was concluded that friction sparks from aluminum alloy (2024-T3) would not cause ignition of gasoline, JP-4, or kerosene, but sparks from other common aircraft materials (titanium, magnesium, chrome-molybdenum steel, and stainless steel) would.

Most of the literature on spark technology concerns use of spark characteristics to establish material identity. The referenced article "Spark Atlas of Steels" by G. Tschorn, 1963, characterizes titanium and iron as highly

luminous spark materials, and aluminum and magnesium as materials without luminous sparks. Both aluminum and magnesium in the molten state retain the color of room-temperature metal. With substantial superheat of the melting point, a red glow can be achieved. A similar review was made of metal removal and cutting fluids technology. Significant points are: (1) cutting speed determines how the cutting fluid meets the chip and enters the space between chip and work piece; (2) cutting oils may lubricate and prolong tool life under given conditions, or cool and also prolong tool life permitting higher cutting speeds; and (3) CO_2 and N_2 may be used as cutting fluids in gaseous form with beneficial effect.

Flammability and spark characteristics of existing tools were noted in the State-of-the-Art Survey, Appendix A. Most supplier tool catalogs and literature make no reference to the subject. Others make carefully guarded and restricted statements which confirm the formidable nature of metal removal cutting in flammable environments.

2.2.3 Review of Concept Design Report

Concept design alternatives were prepared, summarized in a report and presented to AFESC in January 1981.

2.2.4 Preliminary Concept Design

Following approval of concept design alternatives, detail system design commenced. The design process is iterative, progressing from design to test to analysis and back to design, to incorporate test and analysis conclusions and requirements. Design phases described in 2.2.4, 2.2.5 and 2.2.6 were conducted iteratively. To simplify explanation of the Technical Approach, these phases are described sequentially. The initial design employed a reciprocating saw. Various functional tests were conducted, as discussed in 2.2.5. To permit faster cutting, a circular saw was examined with various spark control and management features.

2.2.5 Component and Functional Tests

A series of component and functional tests was conducted to establish the feasibility of concept designs.

2.2.5.1 Compound Saw Blade. Tests were conducted to evaluate the concept of using a compound saw blade with a central gap for passage of spark containment fluids. (See Figure 3 and Table 1.) It was determined that with a constant cutting effort, cutting speed is reduced. Average cutting speed decreased by 60 percent. Therefore, to achieve the same cutting speed with a compound blade as with a single blade, greater horsepower would be required. It should be noted that increasing horsepower will result in increased tool weight.

Reversing the compound blades so that cutting was accomplished in both directions of the reciprocating movement slowed cutting by 22 percent. Introducing a flow of nitrogen between the blades did not produce significant lubricating effect, nor facilitate chip removal, and cutting speed was not improved.

A compound blade was also tested in an Electric Sawzall Reciprocating Saw at 250 strokes per minute. The cutting time, average 185 seconds, was 3-1/2 times slower than the hand-operated hacksaw, which averaged 53.5 seconds.

2.2.5.2 Reciprocating Saw. Tests showed the reciprocating saw cutting speed, which averaged 26 seconds for 18 teeth per inch, and 74 seconds for 32 teeth per inch, was generally slow, and that matching blade tooth configuration to the material cut was very important.

2.2.5.3 Circular Saw. Testing established that circular sawing could accomplish greater cutting speeds. Compared to hand sawing, speeds could be increased five or more times with dry cutting. Flooding with a cutting fluid tended to decrease circular saw or abrasive wheel cutting speeds.

2.2.5.4 Circular Saw - Spark Management. Major spark fields are generated with circular saws and abrasive wheels. (See Figure 4.) A containment box and a splayed brush barrier was devised to contain and defuse sparks. The box and barrier, in combination with a protective envelope, were effective in containing sparks above the surface, and partially effective below.

However, when achieved with a liquid flow the protective envelope created unsatisfactory working conditions for the rescue operator, with wet footing and feedback spray. (See Figures 5, 6 and 7.)

Work led to development of a unique, lightweight barrier, referred to hereafter as a bristle barrier. The bristles, arranged in brush-like form around the cutter, spray outward as the cutter is advanced. The barrier concept was recommended for use with the saw cutter and the penetrator/cutter. This spark containment system is shown in Figures 10 through 14.

2.2.5.5 Human Factors Models. To achieve an optimum configuration, models were constructed to assess human factors accommodation. The first (shown in Figures 15 and 16) was an in-line arrangement of the spreader, saw, and optional chipping tool. This model was evaluated as too long and difficult to position.

In a second model, shown in Figures 17 and 18, the saw is nested under the spreader cylinder. This configuration was considered superior and more convenient for operator handling.

2.2.5.6 Detailed Concept Design. Design proceeded on the recommended configuration shown in Figures 19 and 20.

2.3 DESCRIPTION OF TOOL CONCEPT

2.3.1 Multiple-Function Capability

The multiple functions of the tool and appropriate rescue operations applications are shown in Figure 21.

2.3.2 Operation in Flammable Environments

Both the saw and routing-type cutters have low spark generation potential. Cutting will be accomplished with a locally jetted stream of Halon 1211 fluid. Wet cutting further reduces spark potential. The penetrator/cutter will be hollow, and a jet of fluid will reach the cutting surface at the extreme tip of the tool, providing protection on first breakthrough to the inner space.

Halon 1211 will vaporize on exiting from the cutting interface and will provide a protective envelope around the cutting tools. If sparks were generated by hitting a steel bolt or cutting hardened surfaces, spark travel would be minimal and would be contained within the protective Halon envelope.

2.3.3 Tool Weight

The tool weight objective is 25 pounds, and it is expected this objective will be achieved. A table listing the component parts of the tool and their projected individual weights is presented below.

ITEM	CURRENT WEIGHT ESTIMATE (LBS)
Spreader	9.0
Cutters	6.0
Spark Management	1.0
Body	2.5
Handles with Halon	4.0
Power Supply Attachment	0.5
Carrying Strap	0.5
Design Provision	1.5
Total	25.0

2.3.4 Power Supply and Support

The power supply will be a system of storage cylinders (air and Halon 1211) secured together to make a compact package. It will be carried manually to the crash scene and placed on the ground in the area of the downed aircraft. With only the tool and lightweight supply hose to carry, rescue personnel may move freely and easily about the downed aircraft. The power supply also may be recharged on the ground without interrupting the rescue operation. Figure 22 is an artist's concept of a rescue worker outfitted with the tool and portable power supply.

2.3.5 System and Subsystem Organization

The system organization is outlined below. Detailed descriptions of system and subsystem concepts are given in Section III.

1.0 Displacing System

- 1.01 Displacing Levers
- 1.02 Displacing Linkage and Reaction System

2.3.5 System and Subsystem Organization (Continued)

1.03 Piercing and Entry Tips
1.04 Driving System
1.05 Auxiliary Feature Mounting

2.0 Cutting System

2.01 Cutter
2.02 Cutter Mounting
2.03 Driving System
2.04 Protection
2.05 Speed Adjustment

3.0 Spark Management System

3.01 Cutting Speed Adjustment
3.02 Fluid Containment and Distribution
3.03 Spark Barriers
3.04 Oxygen Displacement

4.0 Auxiliary Function System

4.01 Auxiliary Cutting - Chiseling
4.02 Auxiliary Cutting - Shearing
4.03 Auxiliary Cutting - Squeezing
4.04 Auxiliary Displacing - Levering/Prying
4.05 Other

5.0 Tool Body System

5.01 Housing
5.02 Surface Finish/Color
5.03 Name Plate

6.0 Tool Operating Handle System

6.01 Handles
6.02 Adjustment

2.3.5 System and Subsystem Organization (Continued)

7.0 Power Supply System

- 7.01 Power Supply Attachments
- 7.02 Lines
- 7.03 Fluid

8.0 Power Source System

- 8.01 Prime Mover
- 8.02 Prime Mover Starter
- 8.03 Mountings
- 8.04 Fluid Storage
- 8.05 Fuel Storage
- 8.06 Hose Reels

9.0 Tool Control System

- 9.01 Displacement Actuator
- 9.02 Cutting Actuator
- 9.03 Auxiliary Function Actuators

10.0 Tool Carrying System

- 10.01 Carrying Harness
- 10.02 Mounting for Auxiliary Tools
- 10.03 Auxiliary Tools

11.0 Tool Storage/Ready Service System

- 11.01 P-10 Vehicle Storage/Housing
- 11.02 Housing Mounting
- 11.03 Spare Cutter/Accessory Storage

2.3.6 Phase I Prototype Design Drawings

Drawings of the Phase I prototype design are shown on pages 52, 53, and 54. They are listed by title below in the order in which they appear in the text.

Drawing Number	Title
AS 81D 498	AMETEK Aircraft Rescue Tool Spreader Assembly
AS 81D 499	AMETEK Aircraft Rescue Tool Cutter Assembly
AS 81D 500	AMETEK Aircraft Rescue Tool Assembly

SECTION III

PROTOTYPE FUNCTIONAL DESCRIPTION

3.1 INTRODUCTION

Assembly of an optimum rescue tool will involve the use of the 11 subsystems listed in Section 2.3.5. These are: displacing, cutting, spark management, auxiliary functions, tool body, operating handles, power supply, power source, tool controls, tool carrying and storage/ready service system. All rescue tool concepts were reviewed for these capabilities. The recommended concept is described in the following sections.

3.2 DISPLACING SYSTEM

Displacing functions involve those portions of the tool which accomplish spreading, prying, levering, wedging, pulling and pushing motions. In effect, the material is displaced rather than cut away from the work site. The primary displacing subsystem of the optimum rescue tool is the spreader jaws. These jaws function both in a power opening and closing mode. When closed, the entire jaw assembly can be used as a crowbar. When opened, the jaws tear as well as spread apart the air frame. In a closing mode, they can crush and/or cut portions of the air frame, such as hoses, strength members, wires, etc.

A two-piston pneumatic cylinder with two rods and end clevis mountings will be utilized. Pneumatic connections are located at the center of the cylinder so that supply and exhaust line flexing or extension will be minimal throughout the 12-inch operating range.

The cylinder is a standard, heavy duty, double-acting, pneumatic cylinder rated for 2500 psi operating pressure. All seals and packings are capable of operating in a temperature range of -40°F to 200°F. Variable orifices are mounted at the cylinder parts so the speed of the jaws opening and closing may be preset to prevent uncontrollable movement of the jaws. The rod is hard chrome-plated and highly polished. The rod wiper is made of polyurethane, double-lip type, to protect the piston rod, bearing and rod seal. The rod gland cartridge holds the seal cartridge assembly. This eliminates the need for cylinder disassembly to replace the rod seals or rod bearings.

Jaws are forged aluminum alloy with hardened steel insert piercing tips and shear cutters. Hardened steel pins are used for pivot points with high pressure superfilament Teflon® bushings.

3.3 CUTTING SYSTEM

The cutting system includes those portions of the tool which shear or otherwise cut the metal by kerf removal. Cutting actions include routing, chiselling, axing, piercing and shearing. Cutting can be accomplished with a variety of routing cutters, chisels, the sharpened edge of the jaw, a reciprocating chisel, punch, and the closing/shear action of the jaws. Axing is accomplished when the entire tool assembly is swung, utilizing the lower outer edge of the jaw as an axe blade.

The reciprocating saw and drive motor and penetrator/cutter and drive motor are nested together and mounted on common brackets. The tool has a muffled rear exhaust which gives a sound level of 80 dBA at free speed (in accordance with ANSI S5.1-1971 CAGI-PNEUROP test code).

3.4 SPARK MANAGEMENT SYSTEM

A hand-operated metering valve will be used to control the flow of Halon 1211 from the pressurized reservoir on the rescue tool to the discharge nozzles mounted at and within the router tool. Halon flow will not be required when cutting through canopy plexiglas materials. A makeup reservoir is included with the pneumatic cylinder drive package.

A lightweight bristle barrier will be located around the routing cutter and oriented to splay outwards as the cutter is brought to the surface and penetrates.

3.5 AUXILIARY FUNCTION SYSTEM

Auxiliary functions include those attachments, spare parts and consumables that will enhance, maintain or support the rescue tool's operation. These include the use of quick change cutters, chisels, and punch heads, "can opener" fixtures, tool storage scabbard system, pick and hammer assembly. A combination of these auxiliary components may be added to the tool to increase or extend its capability.

3.6 TOOL BODY SYSTEM

The tool body system includes those portions of the tool which are used to encapsulate the power and control components and to react to internal forces, as well as to transmit and react operator-imposed and cutting reaction forces. The tool body system is intended to shroud components and drive linkages, and prevent unnecessary dirt and debris from entering the assembly. Tool handles, fairings, and sling attachment points are an important part of the tool body. Auxiliary tool systems will interface with and/or be stored on the body as required.

3.7 TOOL OPERATING HANDLE SYSTEM

The tool operating handle system fulfills two functions. The first of these is to provide a means for carrying the tool and directing its various subsystems at the work site. Second, tool controls are mounted on the handle system for controlling the saw, spreading jaws, and any auxiliary power systems. Handles must be positioned to maximize both the tool and operator's capabilities during all phases of the rescue operation. These phases include: carrying, positioning at work site, tool operation and system control.

3.8 POWER SUPPLY SYSTEM

The high pressure air storage cylinder has an operating pressure of 2200 psi and a volume of 45 cubic feet. This cylinder is the same as that used by Air Force rescue personnel for its air breathing systems and is ASME coded. The cylinder is equipped with the following:

- o Cylinder shutoff valve
- o Quick disconnect valved coupler
- o Flo-Fuse (excess flow check valve)
- o Umbilical hose (rated at 3000 psi operating pressure) with quick-disconnect-valved nipple at end

The umbilical hose or whipline is connected to the rescue tool by plugging into the quick disconnect valved coupler.

A high pressure flexible hose rated for 3000 psi pneumatic service can be reeled out from the rescue truck's high pressure air source and plugged into the rescue tool's air storage cylinders quick disconnect valve. This gives the rescue tool operator the capability of operating for longer periods of time. A Flo-Fuse is installed at the high pressure air source on the rescue truck and will automatically shut off the air flow in case the umbilical hose is severed. A schematic of the pneumatic system is shown in Figure 26.

3.9 POWER SOURCE SYSTEM

The power source consists of a high pressure air storage cylinder and the Halon 1211 storage cylinders. The three cylinders will be strapped together to make a compact, secure package. As the supply hoses leave the power source package, they will be combined with a twin-line hose to make a more compact, easily handled supply hose system. Also connected to the power source package will be a storage system for the twin-line supply hose. This storage system will allow the hose to be easily advanced without entanglement.

The storage cylinders for both the air and Halon 1211 systems will consist of a shutoff valve and special replenishment connection. The replenishment connection will be a manifold consisting of a quick disconnect valved coupler on both ends. One end of the manifold will connect to the rescue tool supply hose, while the other end will allow additional storage cylinders to be quickly connected while the rescue continues uninterrupted.

For ease of carrying, there will be attachments for a shoulder sling and handle.

3.10 TOOL CONTROL SYSTEM

A control system will be provided for the rescue tool to direct the separate functions of cutting and spreading, and the auxiliary features. The control system is a block manifold containing control valves. Control levers and linkages are mounted on the handle surfaces. These controls must be configured to prevent their inadvertent activation. Control levers must be suitable for operation by individuals wearing heavy gloves and having less than normal tactile sensation. All controls will be failsafe. When routing, release of the trigger will cause the blade to stop. Release of the spreader control will stop the jaws from further movement.

From the quick connect valve, the air supply goes to the jaws-actuating cylinder and router selector valves mounted in the body of the rescue tool. The selector valve for the jaws-actuating cylinder is rated for 3000 psi working pressure and is four-way, closed center, three-position. The valve provides the necessary flow patterns for operating the double-acting cylinder. The internal shear seal valves are made of plastic so lubrication of the valve is not required. The ball valve for controlling the air supply to the router is two-way shutoff, two-position, of stainless steel with Teflon® seals.

Between the ball valve and the router trigger switch is a pressure-reducing valve. This valve is a direct acting, self-contained, gas dome regulator of compact design. It ensures fast, sensitive, and accurate response, while preventing erratic operation. It is extremely rugged and lightweight. Sudden changes in flow rates are smoothed automatically, and valve and seat wear, valve chatter hunting, and other harmful effects are eliminated.

A safety relief valve is installed between the regulator and the router to protect the operator in case the air pressure exceeds 120 psi. The valve is the popoff type. It is adjustable only from the inlet side (for safety against tampering), permits precise setting of cracking pressure, is absolutely leak proof, and gives virtually maintenance-free operation.

A midget-sized pressure gauge is mounted into the rescue tool to give the operator the air supply pressure available. The window of the gauge is plexiglas for durability.

3.11 TOOL CARRYING SYSTEM

A tool carrying system is necessary for transport of the tool to allow the operator free use of his hands. Such a system would be a shoulder sling assembly incorporating storage for consumable tool components. The sling must

be positioned and configured not to interfere with the normal operation of the tool. Incorporation of an umbilical quick attachment point in the carrying sling allows the umbilical to be positioned in a way that it will not be endangered by the tool's cutting and displacing components.

3.12 TOOL STORAGE/READY SERVICE SYSTEM

The tool storage and ready service systems include areas on the rescue vehicle for stowage of the rescue tool and power supply. The rescue tool, auxiliary components and power umbilical must be stored in a manner which will permit rapid deployment. Sufficient air must be carried for the total rescue operation. Tool spares and those systems required to keep the tool functioning during the operating period are part of the tool storage and ready service system.

SECTION IV

RISK ASSESSMENT

4.1 INTRODUCTION

A tool has been designed to meet the design objectives listed in Section 2.1. Those objectives considered to be most critical to successful functioning are:

- Ability to operate in flammable environment.
- Ability to integrate the variety of functions needed for effective rescue into one tool, and simultaneously meet the weight objective.
- Ability to successfully cut a variety of materials.

4.2 OPERATION IN FLAMMABLE ENVIRONMENT

Ability to operate in a flammable environment is considered the most critical functional objective of the tool. It would be possible, should one spark evade the the spark control system, to cause fire or explosion. Accordingly, an approach has been taken to achieve successful operation in flammable environments through system redundancy and use of a low spark potential cutting system.

Cutting speed is a key parameter of the tendency to generate friction sparks. For example, in sawing, a hand-operated hacksaw does not generate sparks, while a high speed circular saw, grinding wheel or abrasive wheel may generate a substantial number of sparks. The routing-cutting concept

recommended will use a conically-shaped point, which operates at a cutting speed of zero at the central point to a maximum peripheral speed of 3000-3500 fpm — approximately 1/4 to 1/3 of circular saw and abrasive wheel speeds.

Special features will be incorporated in the cutting tools to optimize rescue performance:

- Large relief angles to minimize buildup of frictional heat
- Large relief angles to facilitate flow of Halon 1211 coolant suppressant for contact with metal removal chips and creating a protective envelope
- Piercing point for creating entry through panel surfaces
- Tooth form to maximize cutting traverse speeds through a variety of alloys: aluminum, magnesium, steel, and a variety of plastic materials
- Use of high speed, red-hard, red-wear tool steel such as M2 to enhance ability to hold a keen, tough cutting edge at high speeds, and to enhance toughness with a fine grained matrix.

The recommended design concept has a high probability of success for safe operation in a flammable environment. The final answer must await construction and test of a prototype unit. Developmental details to facilitate adjustment and tuning to meet objectives include Halon nozzle placement and characteristics, the cutting tool (see above), speeds, pressures, flow rates, and special alloy tool tips.

See Table 2 for detailed risk assessment for operation in a flammable environment.

4.3 WEIGHT OBJECTIVES

The recommended design concept employs proven friction components which are basically lightweight. The router cutter, for example, is the lowest weight per horsepower mechanical type cutter available. Lightweight features include:

- o pneumatic drives
- o forged aluminum alloy jaws
- o high strength, heat-treated steel linkage pins
- o plastic (superfilament) bushings
- o router cutter
- o small-diameter umbilical hose (similar to gas welder hoses).

Current weight estimates indicate weight objectives can be achieved.

Potential problems exist with the addition of carrying loops for hand tools, including the seat belt cutter and the seat ballistic hose reach rod cutter. The problems could be manifested as an accumulation of weight or bulk impeding movement and tool usage.

A weight of 52 pounds is estimated for the power pack, which is moved as close as possible to the tool use point, and is then left on the ground (analogous to the tank and reach hose-type home vacuum cleaner). The man should be able to carry the tool, the power pack, and the connecting lightweight hose. Alternatives include team carry or wheeled-assist carry, as with a golf-bag-type two-wheel pull dolly.

4.4 CUTTING OBJECTIVES

The tool employs versatile cutting concepts which have capabilities well suited to use in rescue operations. Traditional circular saws and abrasive wheels cut in straight lines only and cannot make corners. The router can make penetrating holes and a curved or rounded path.

The router is used extensively by air frame manufacturers in cutting and shaping a wide range of aircraft structural panels and components.

In meeting cutting objectives, it is anticipated that router cutter tool development will be pursued to establish an optimum universal cutter for a variety of materials, including steel. Study will also be required to establish effective length based on distance reached inward from the guiding surface for internal frames, ribs, etc.

Cutting fluid placement and flow are key parameters in cutting and must be considered in development.

The tool is assessed to have a high probability of meeting cutting objectives for plastic, aluminum, magnesium, and titanium, and a somewhat lesser probability for structural steel materials. However, steels hardened throughout, case hardened, or hardened in local areas cannot be cut by the router. Such materials require abrasive cutting, which has been shown to have a high spark propensity. It is believed that rescue entry may be achieved without cutting hardened steel. The saw cutter increases the versatility of the tool.

4.5 OTHER RISKS

A special long-reach hand cutter is used for cutting ballistic hoses on all types of aircraft egress ejection systems. The recommended rescue tool

has a shear in the spreader system capable of shearing ballistic hoses. The shear however, does not include (at this time) a U-section plug cutter as currently required for ballistic hoses. If testing of the prototype tool is successful this requirement may be deleted.

SECTION V

RECOMMENDATIONS

It is recommended that development of the rescue tool continue with a Phase II Project to complete detail component design sufficient for prototype construction and subsequent testing.

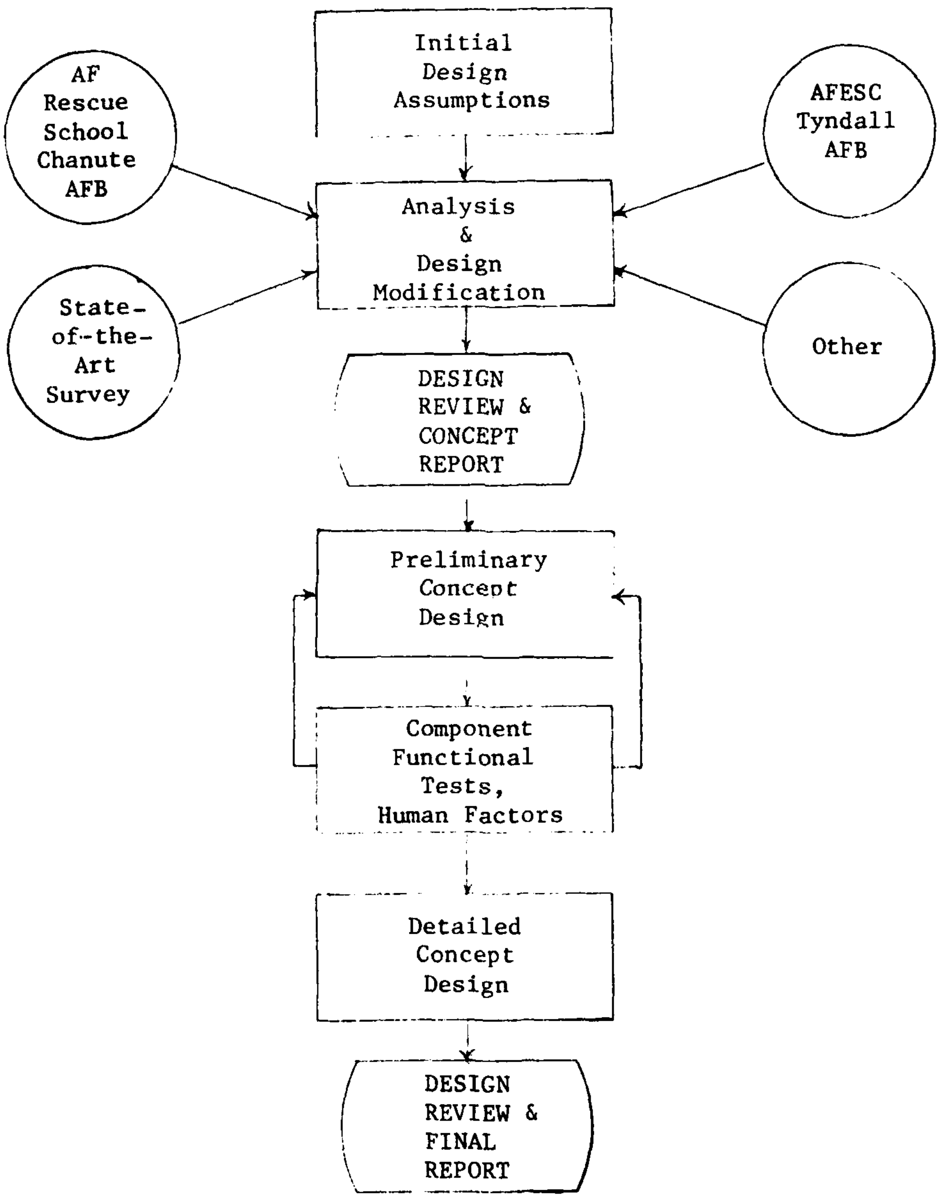


Figure 1. Block Diagram Overview of Technical Approach.

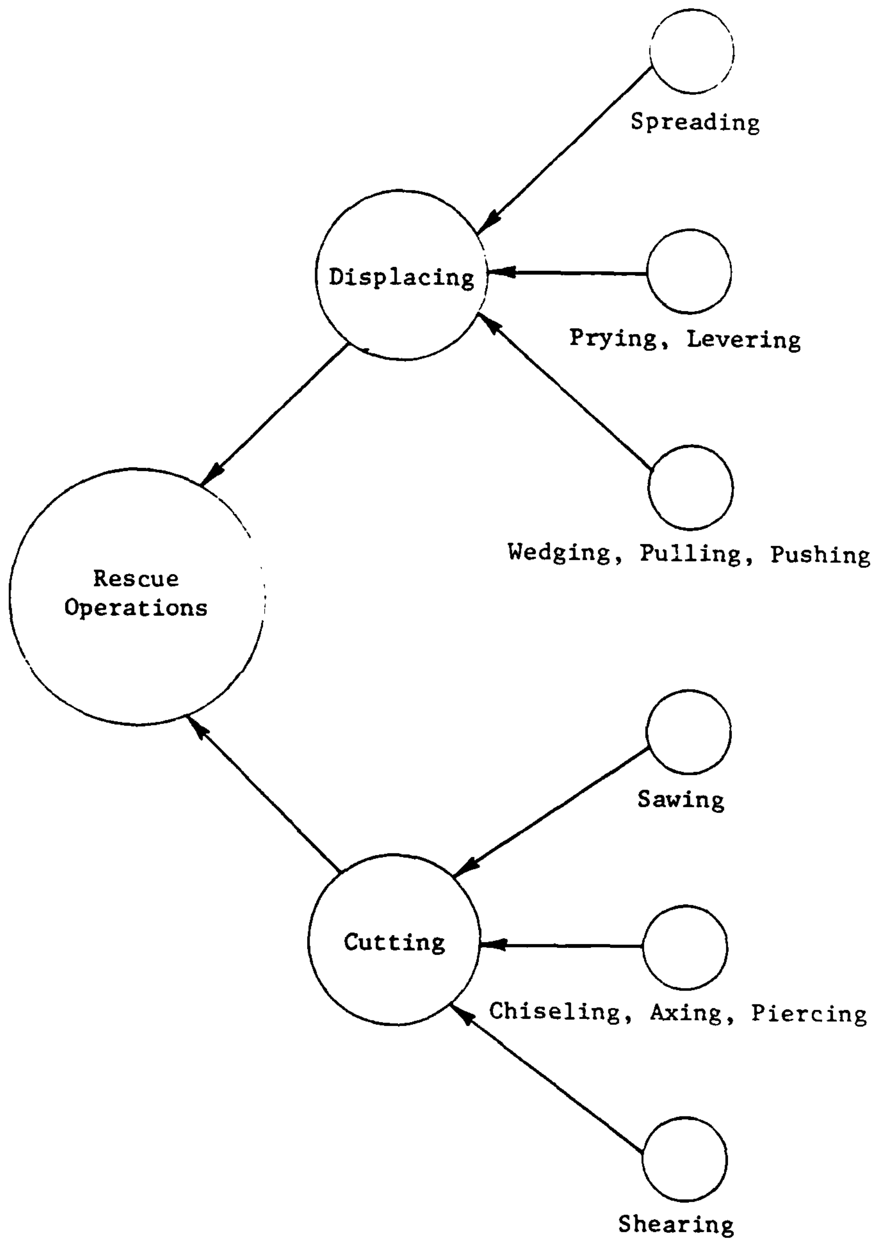


Figure 2. Basic Functions Required in Rescue Operations.

Figure 3. Compound or Double Saw Blade With Central Gap for Gas Flow with Nitrogen Supply Connections.

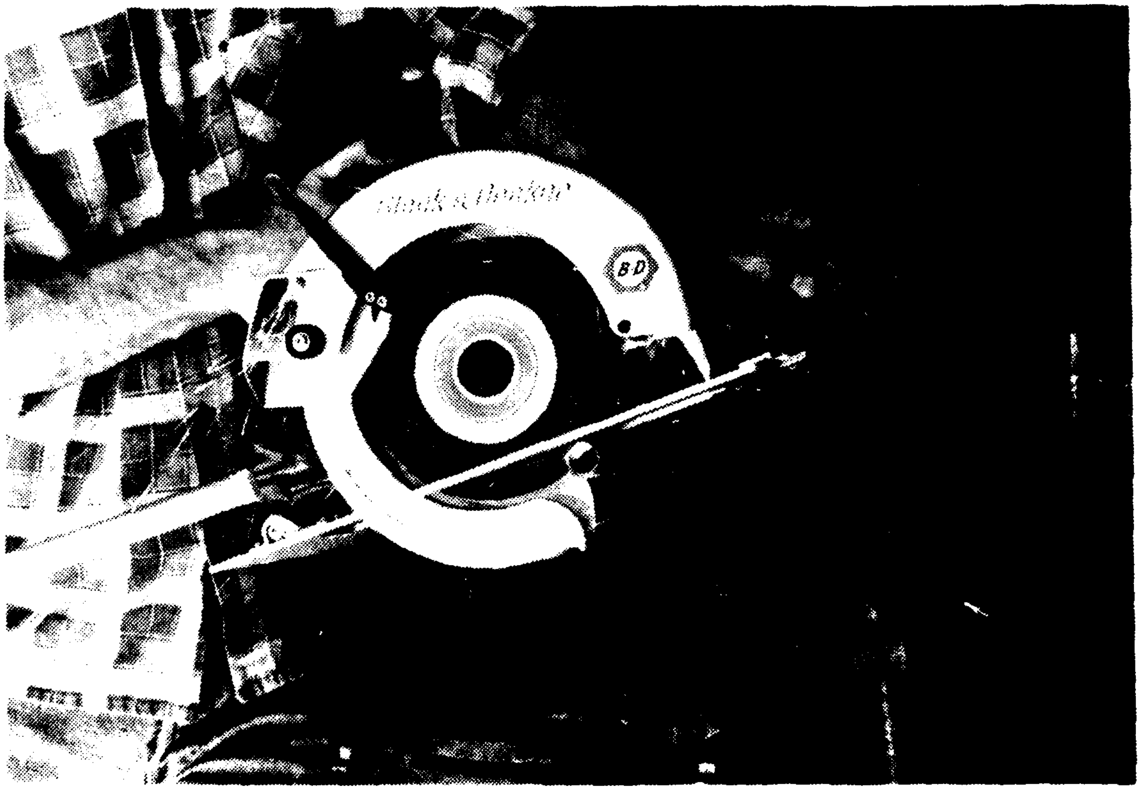


Figure 4. Pneumatically-Driven Circular Saw With Abrasive Wheel Showing Spark Field Cutting Steel Pipe.

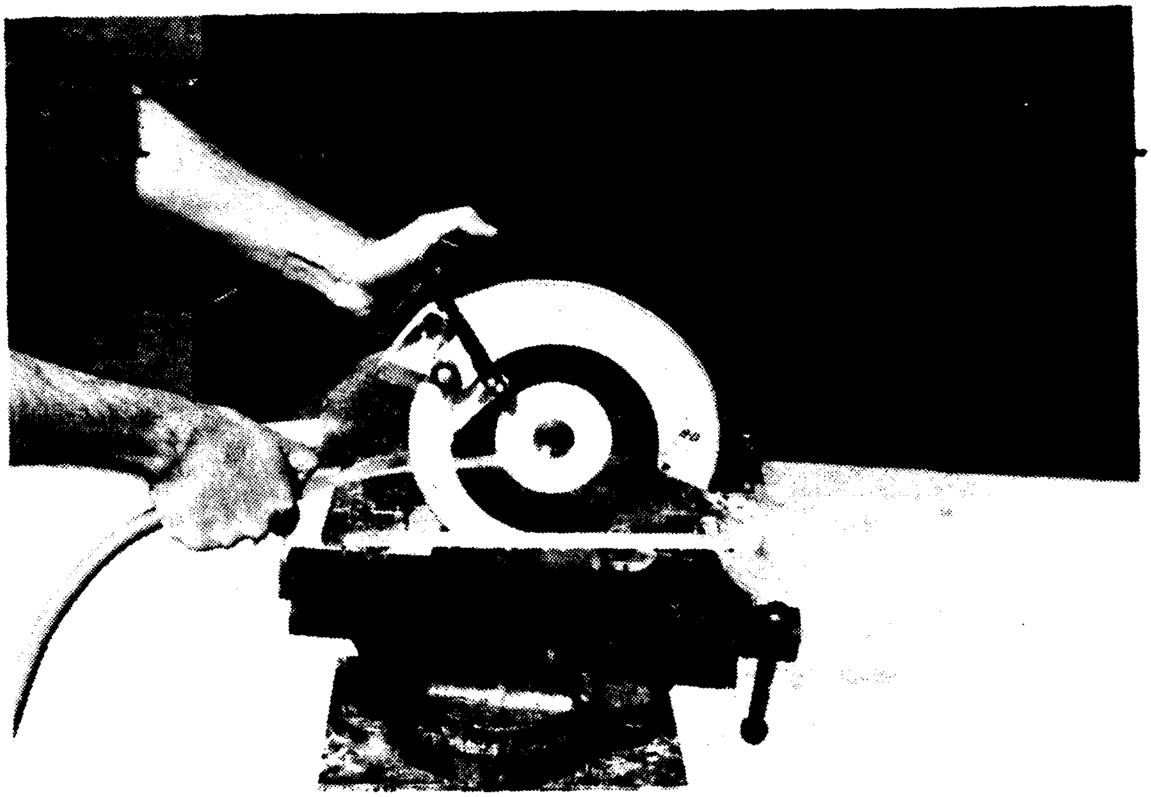


Figure 5. Circular Saw Showing Placement of Locally-Directed Fluid Stream for Creation of a Protective Envelope.

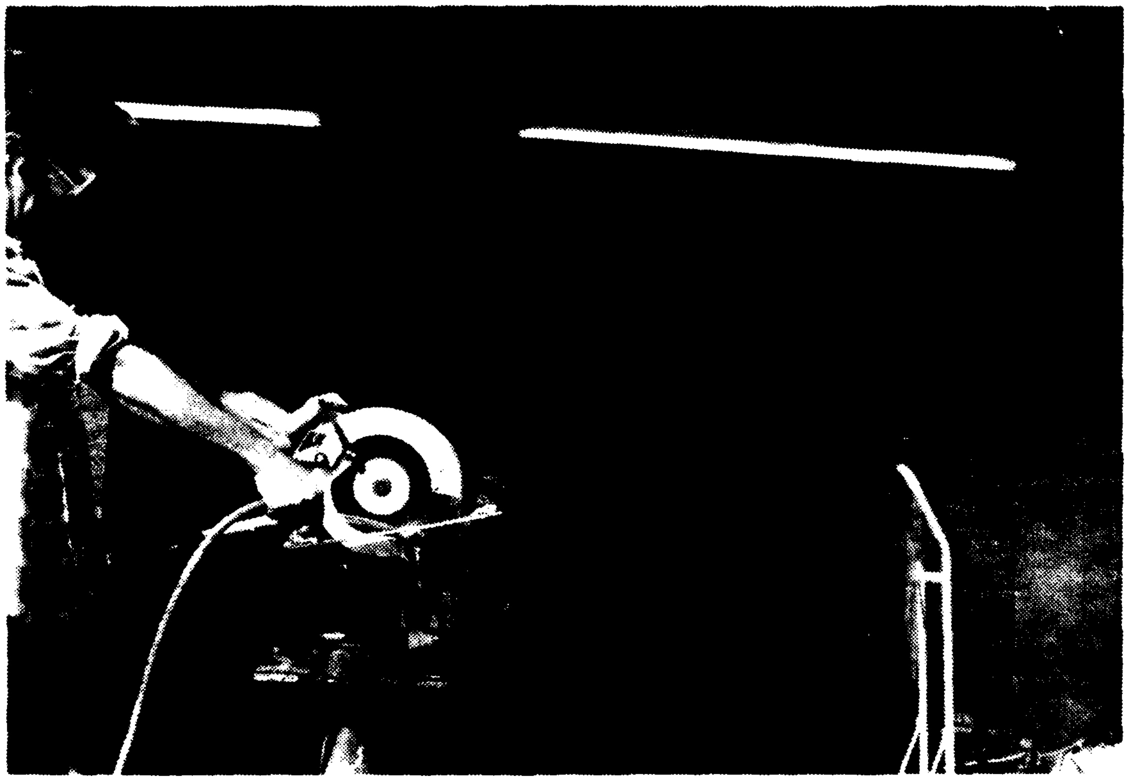


Figure 6. Circular Saw Showing Placement of Locally-Directed Fluid Stream Closer to Cutting Edge.

Figure 7. Circular Saw With Introduction of Fluid Stream With a Delivery Line.

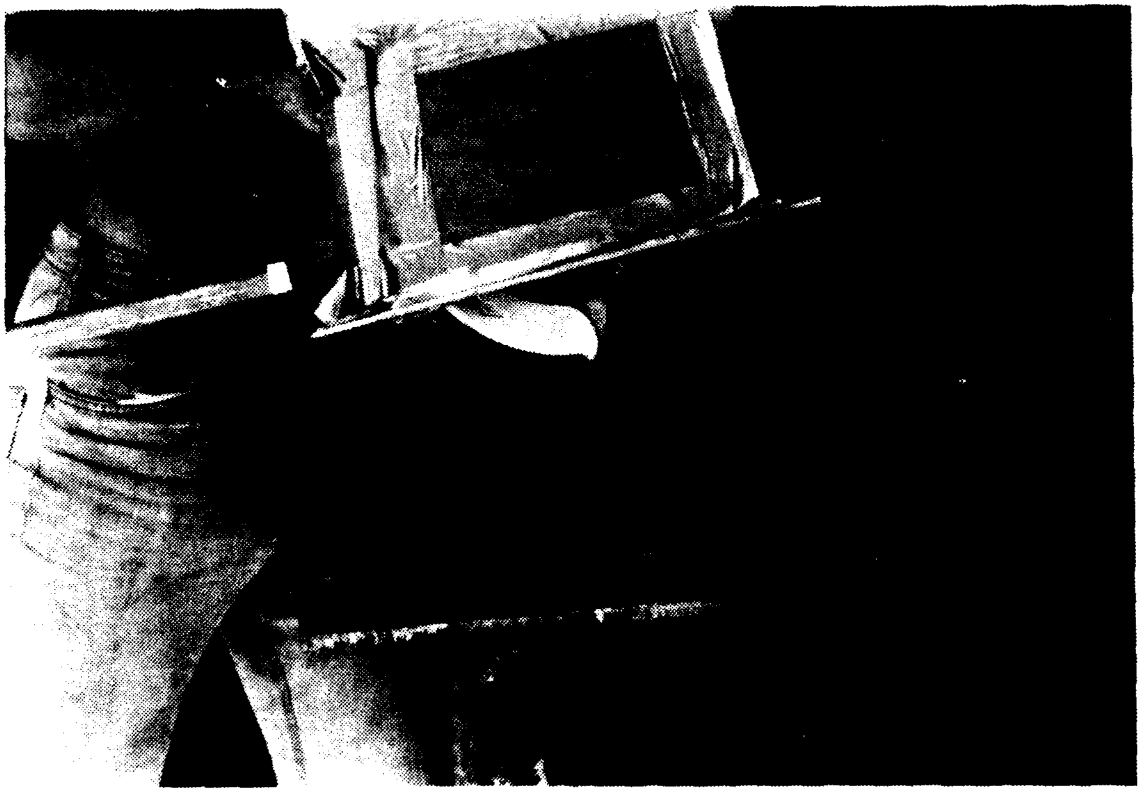


Figure 8. Placement of Simulated Spark Containment Box Over Saw.

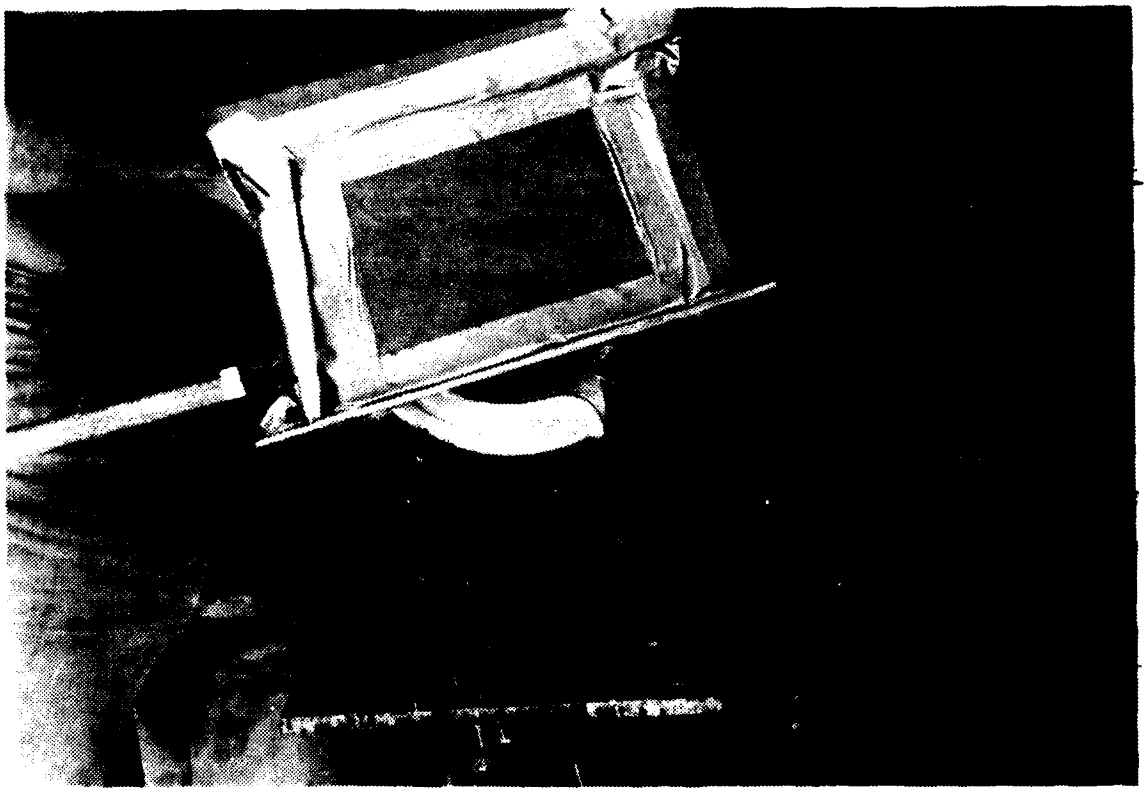


Figure 9. Operation With Spark Containment Box Without Fluid and Bristle Barriers.

Figure 10. Side View of Spark Containment Box Showing Addition of Fluid Supply Lines and Bristle Barriers.

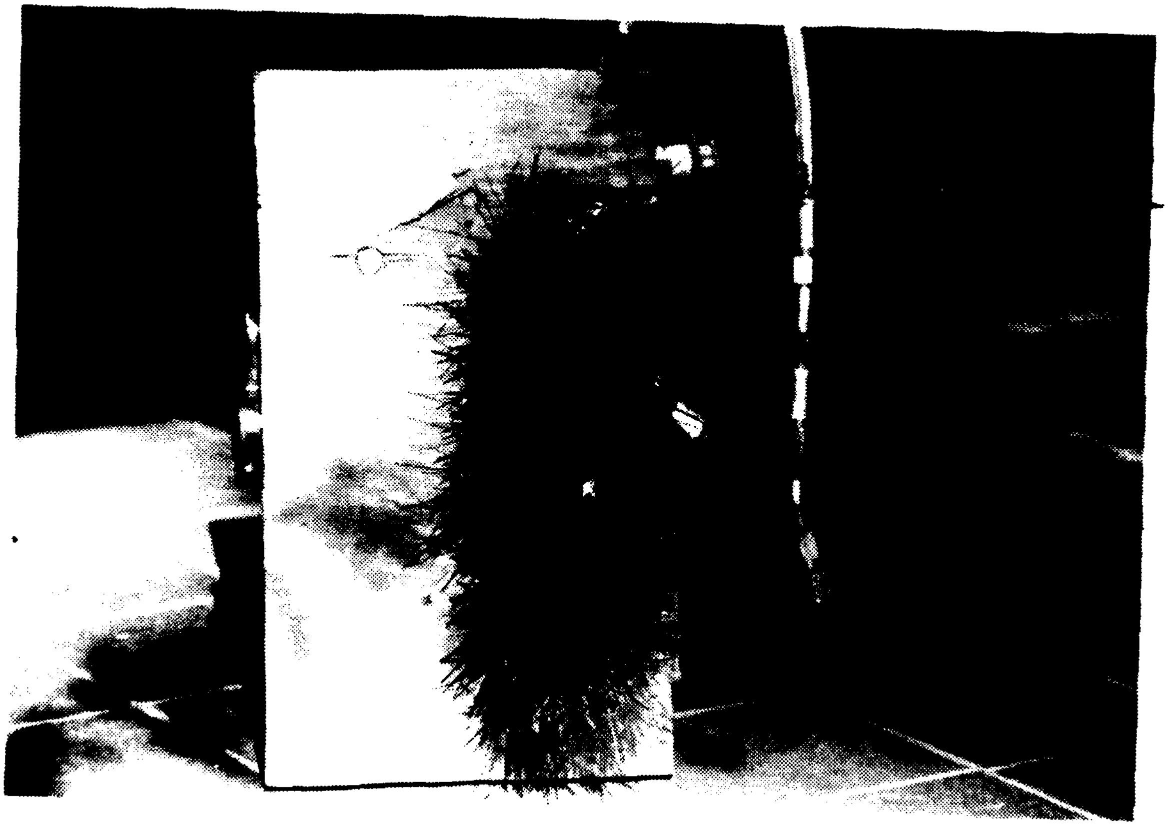


Figure 11. Bottom View of Spark Containment Box Showing Bristle Barrier.

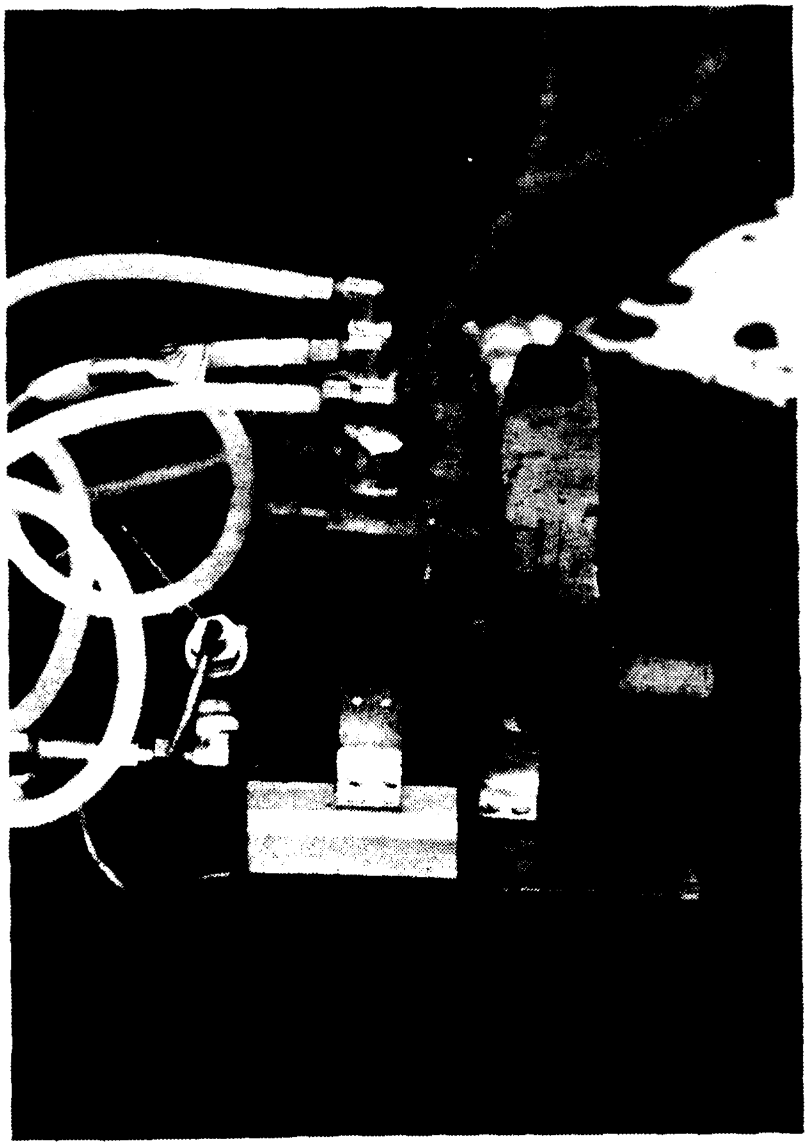


Figure 12. Spark Containment Box, Showing Spark Capture Box, Fluid Supply Lines and Bristle Barriers.

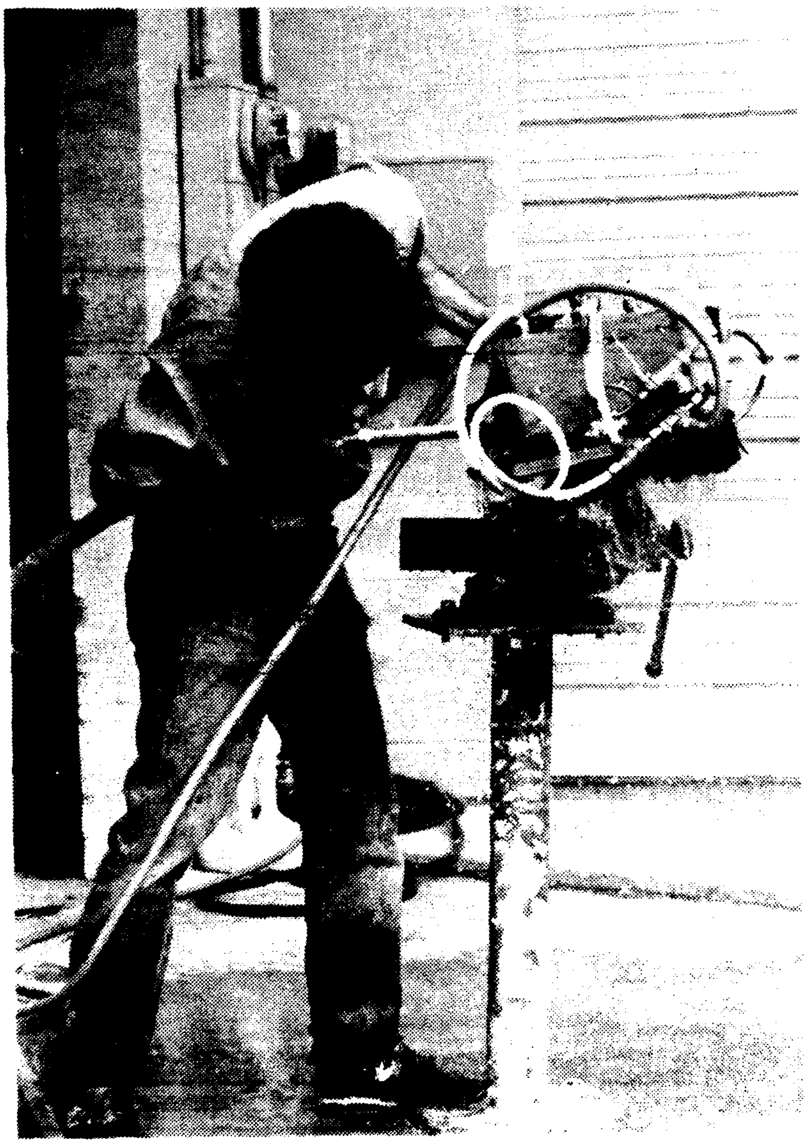


Figure 13. Spark Containment Box in Place, Ready for Cutting.

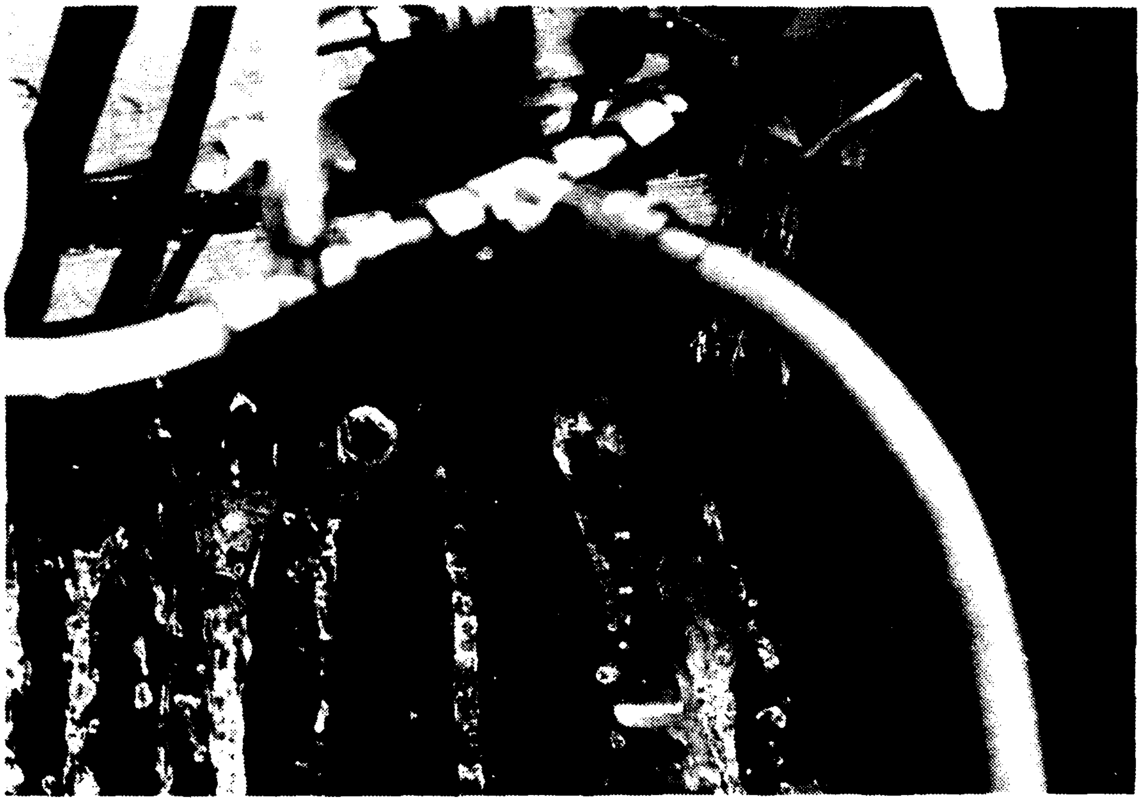


Figure 14. Saw Shown Close-up Cutting Steel Pipe.

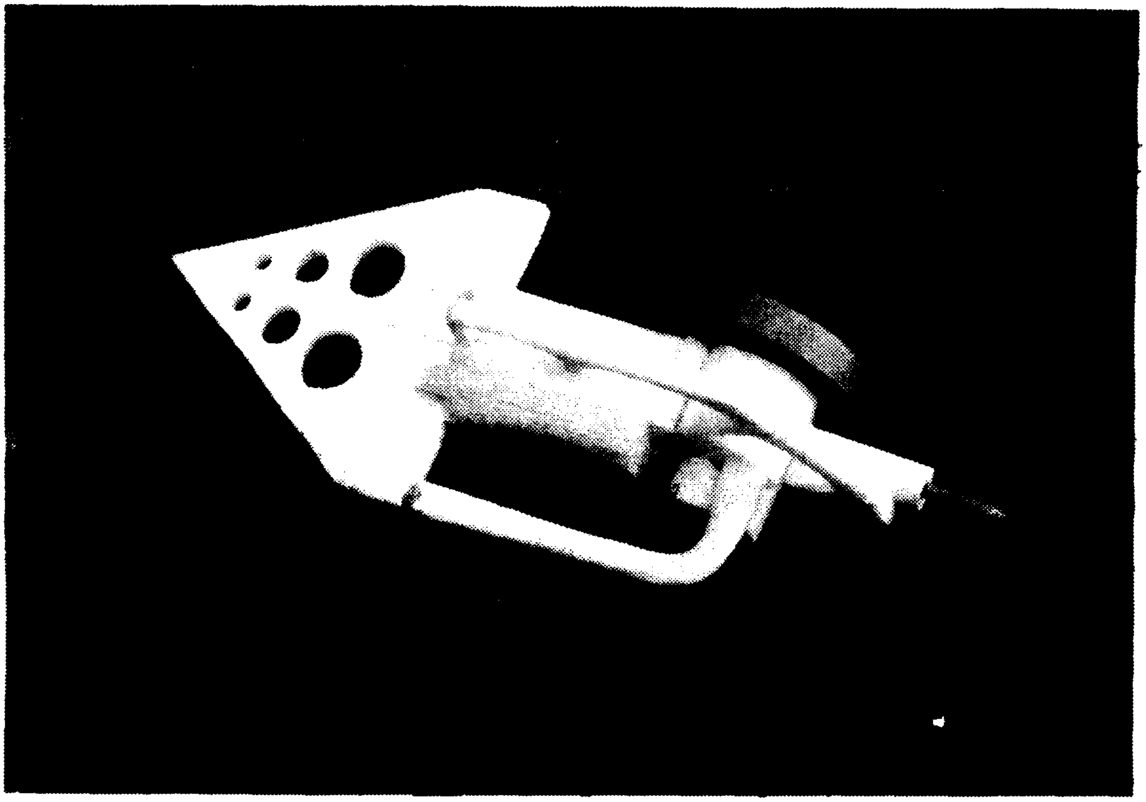


Figure 15. Human Factors Model, Showing Saw and Chipping Tool In-Line With Spreader.

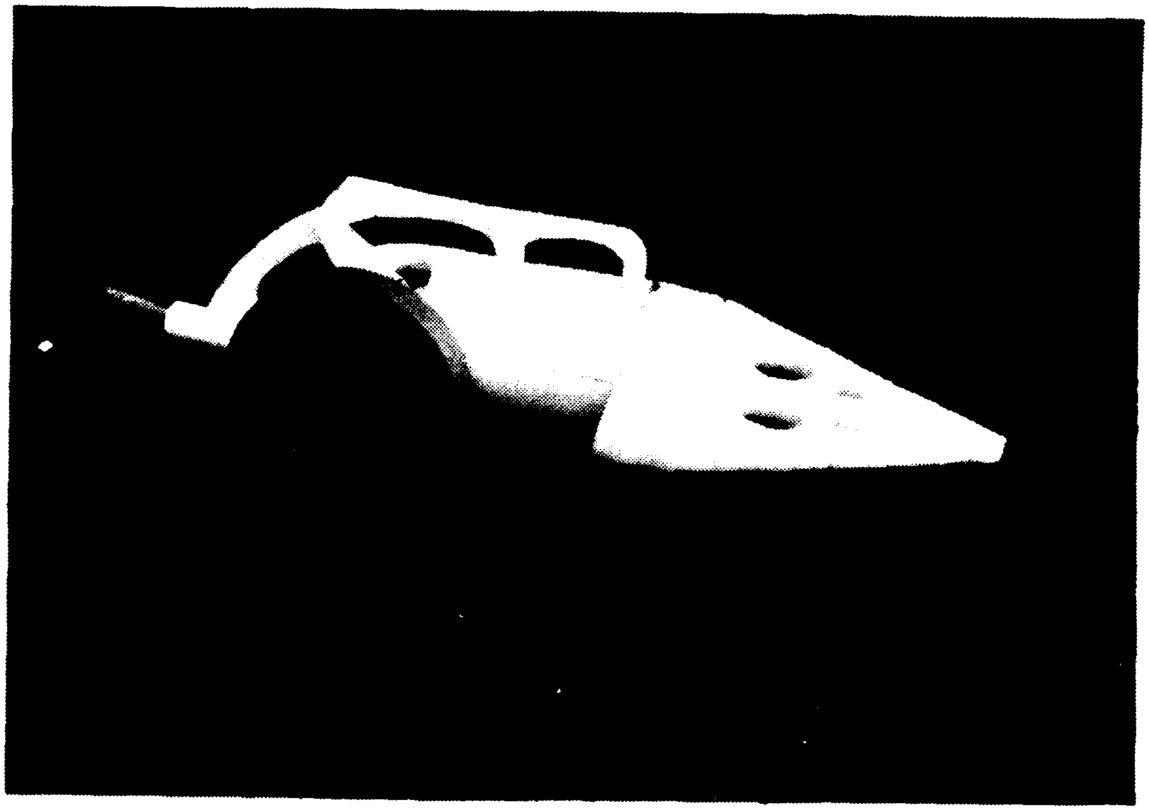


Figure 16. Side View of In-Line Tool Arrangement.

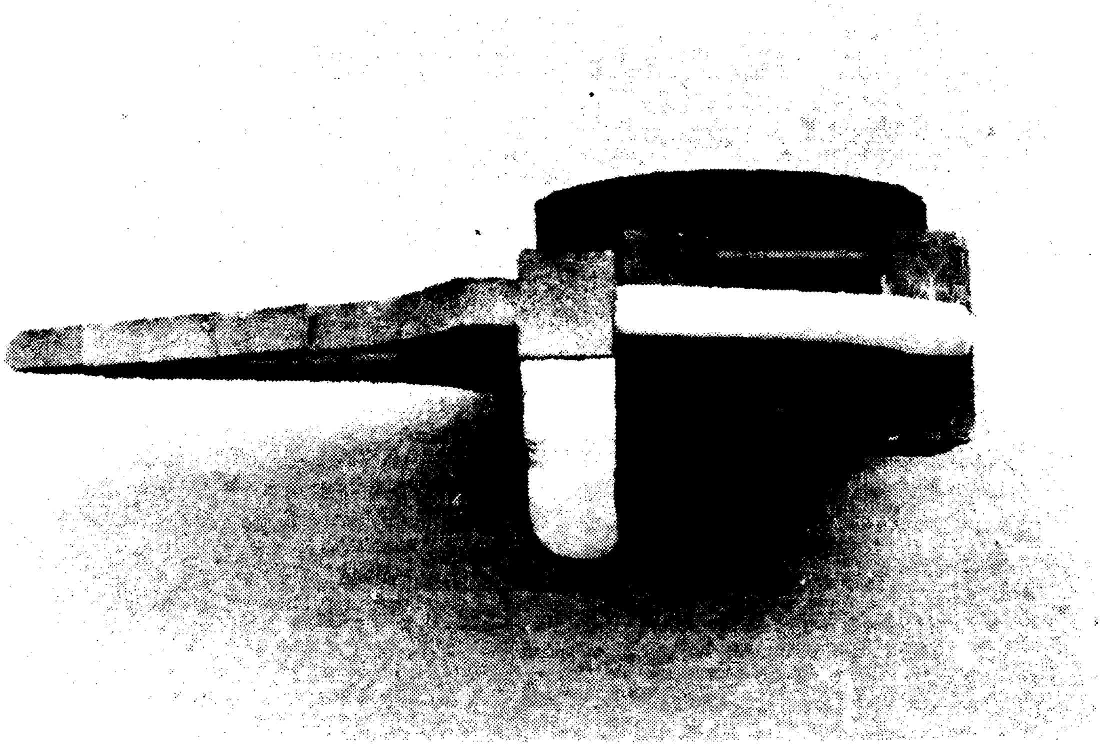


Figure 17. Human Factors Model, Showing Saw Nested Under Spreader Cylinder.

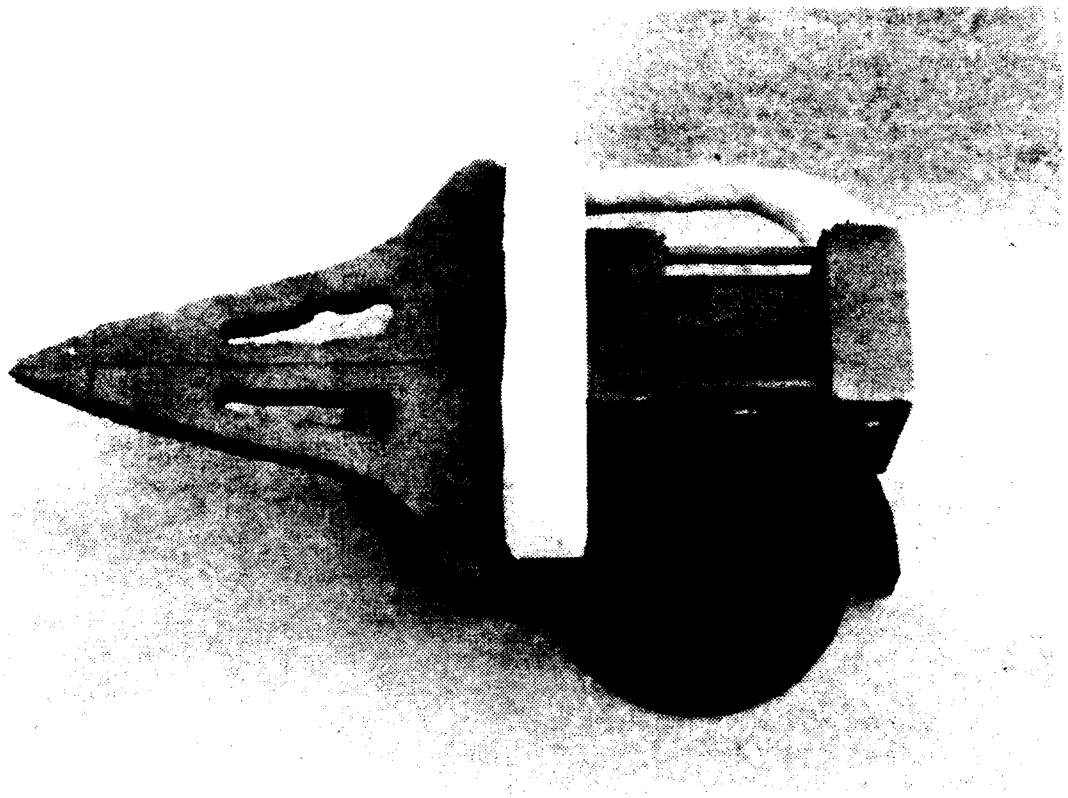


Figure 18. Side View of Nested Arrangement.

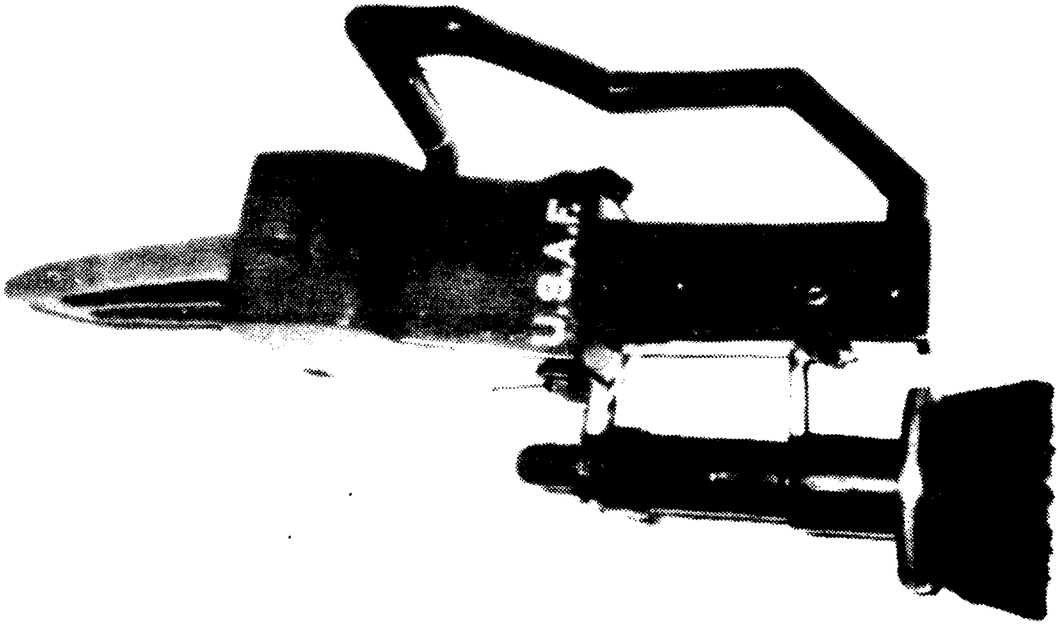


Figure 19. Human Factors Model of Recommended Design, With Transverse Spreader Cylinder, Saw Cutter, and Penetrator/Cutter.

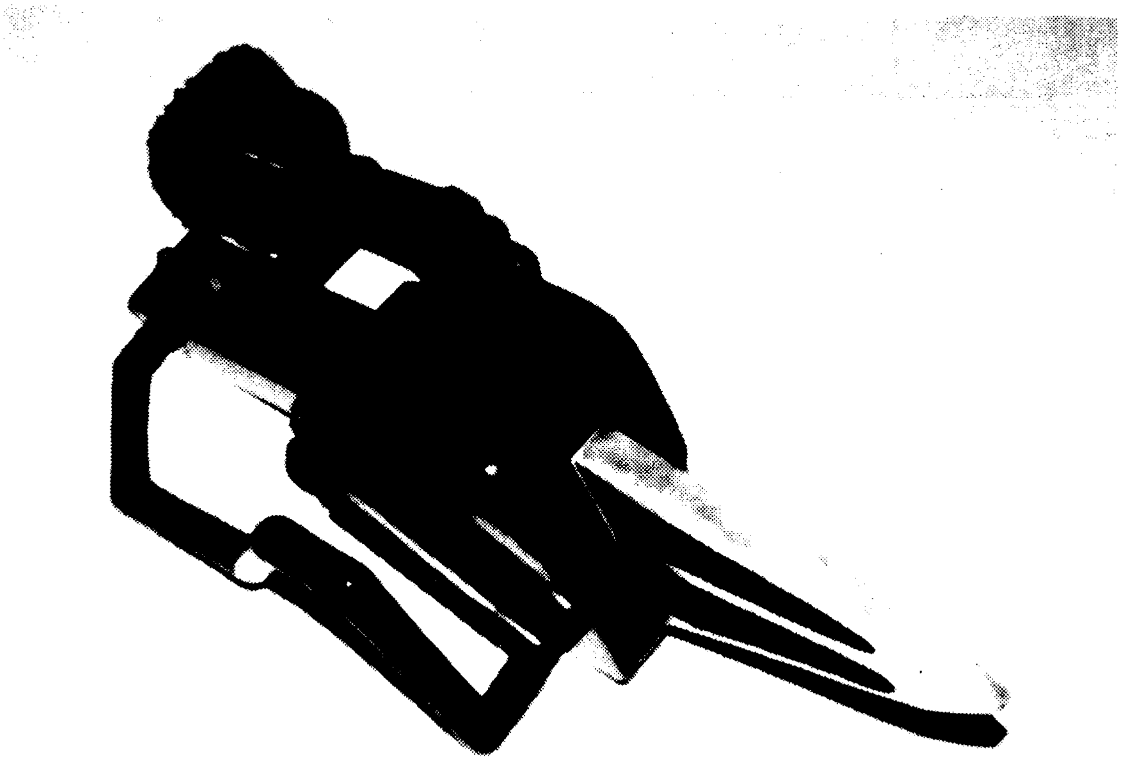
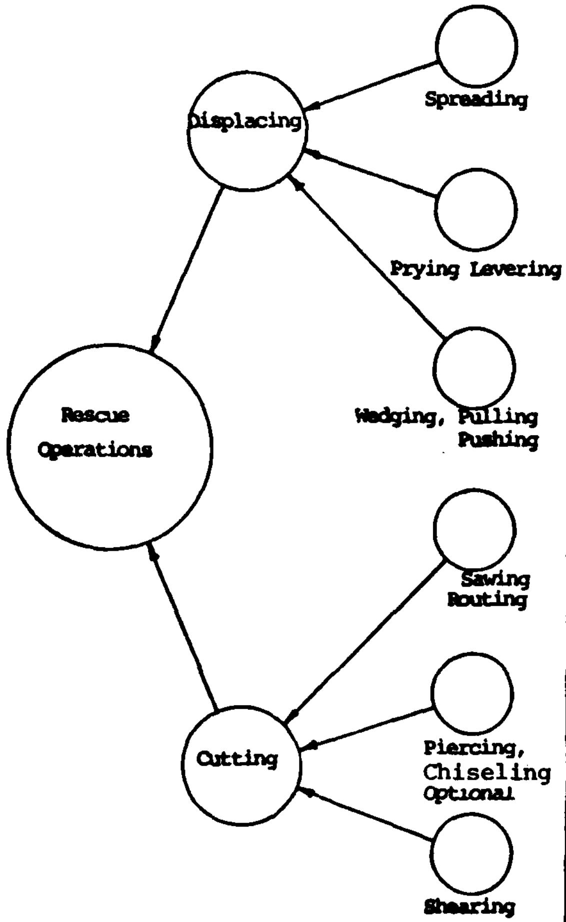


Figure 20. Side View of Recommended Design Showing Cutters and Protective Bristle Barrier.



	Making Man Size Hole	Forcing Doors	Cutting Cables And Hoses
Spreading	x	x	-
Prying Levering	x	x	-
Wedging, Pulling Pushing	x	x	-
Sawing Routing	x	x	x
Piercing, Chiseling Optional	x	x	x
Shearing	x	x	x

Figure 21 Multiple - Function Capability of Tools

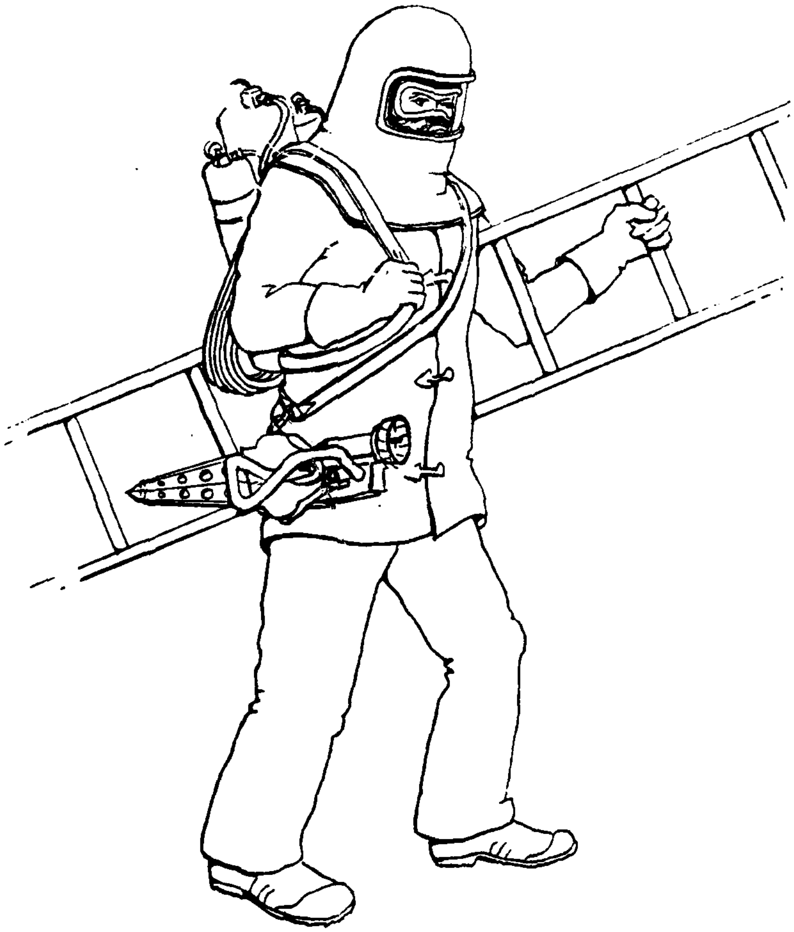


Figure 22. Rescue Worker Carrying Power Supply Tanks, Tool, and Access Ladder to the Rescue Scene

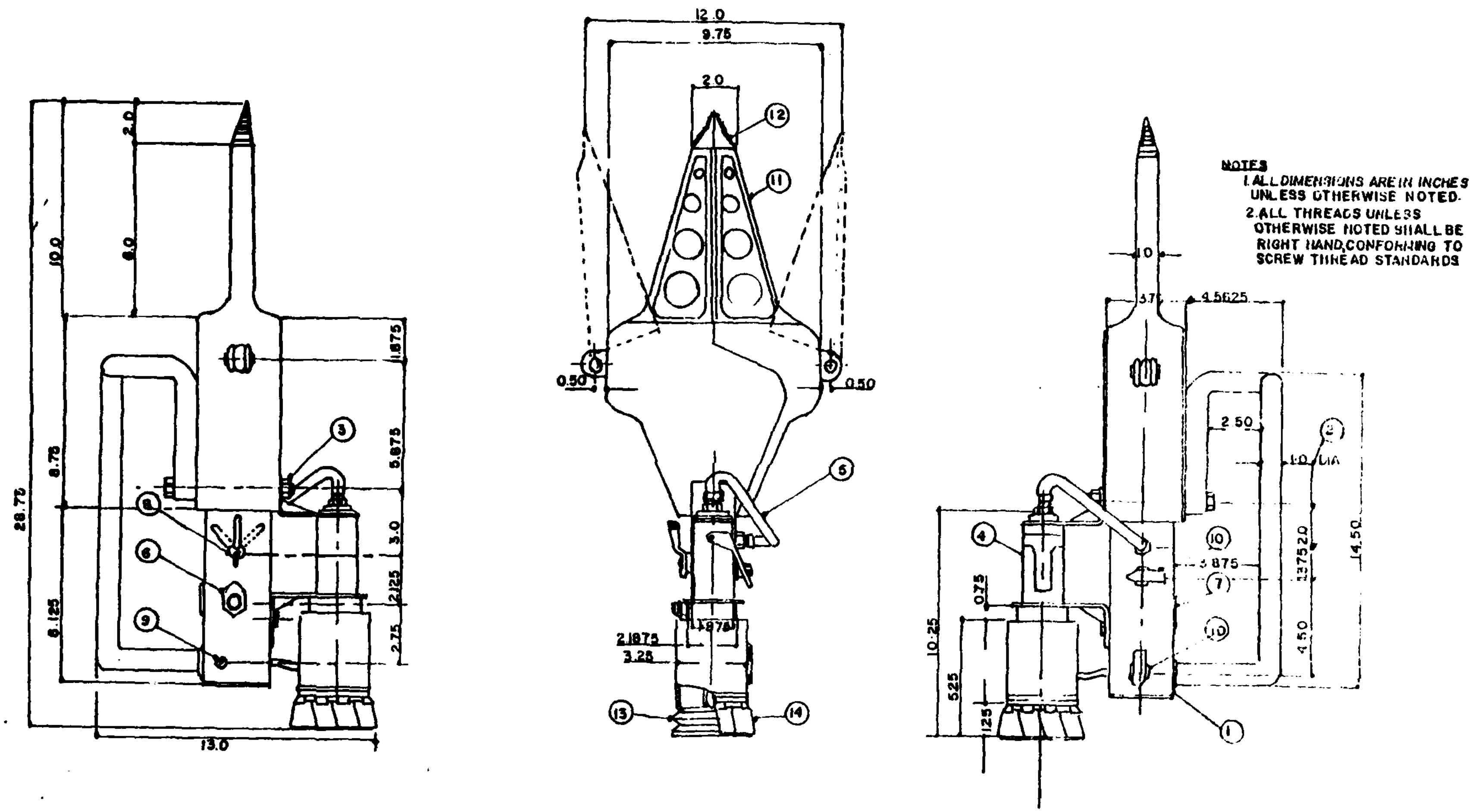


Figure 23. AMETEK Aircraft Rescue Tool Spreader Assemblv

NOTES:

1. ALL DIMENSIONS ARE IN INCHES UNLESS OTHERWISE NOTED.
2. ALL THREADS UNLESS OTHERWISE NOTED SHALL BE RIGHT HAND, CONFORMING TO SCREW THREAD STDS.
3. PARTS ARE TO BE FREE OF BURRS AND OTHER SHARP EDGES
4. REFER TO AS BID 500 FOR ASSEMBLY
5. PATENT APPLICATION PENDING BY AMETEK, INC.
6. DO NOT SCALE FROM DRAWING

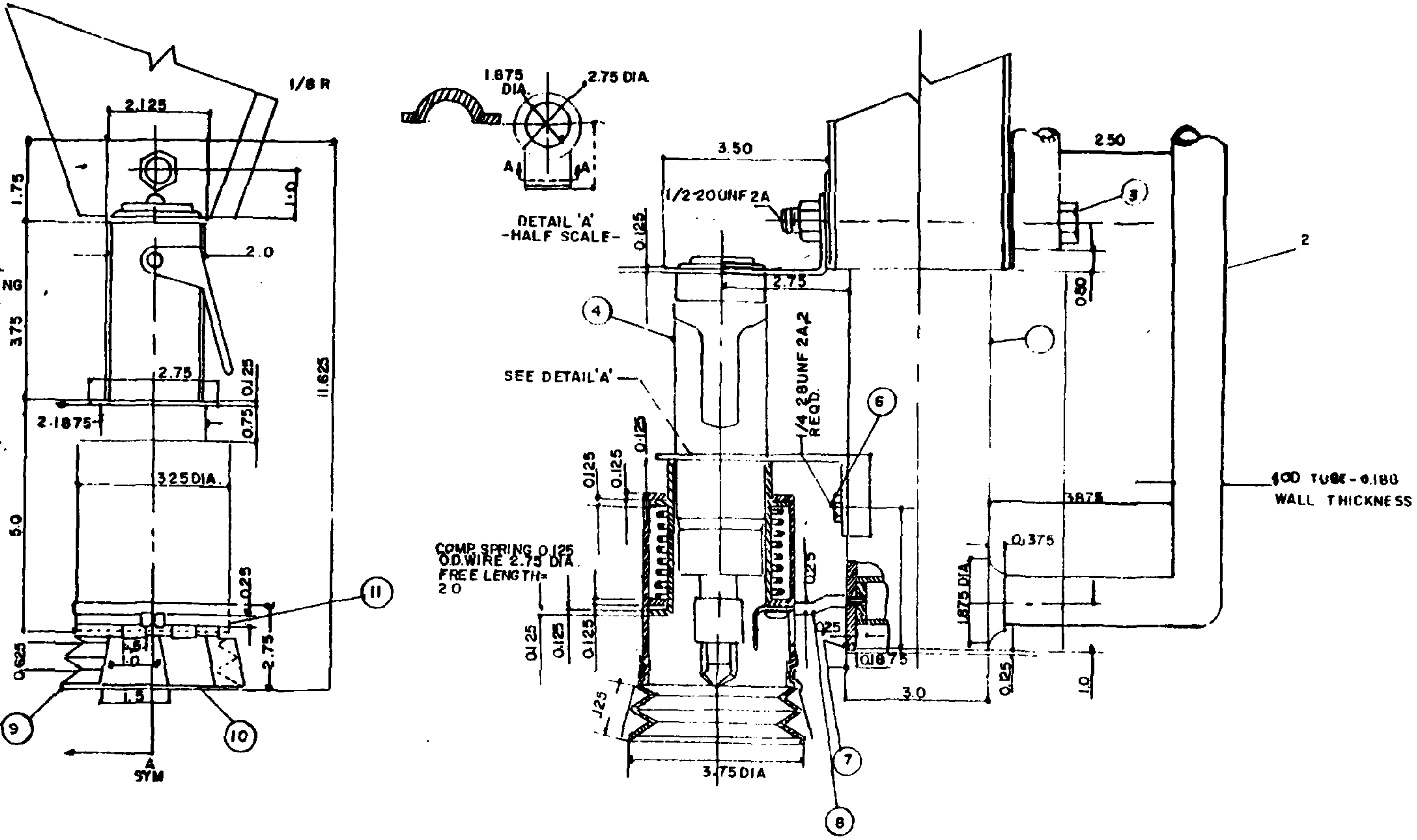


Figure 24. AMETEK Aircraft Rescue Tool Cutter Assembly

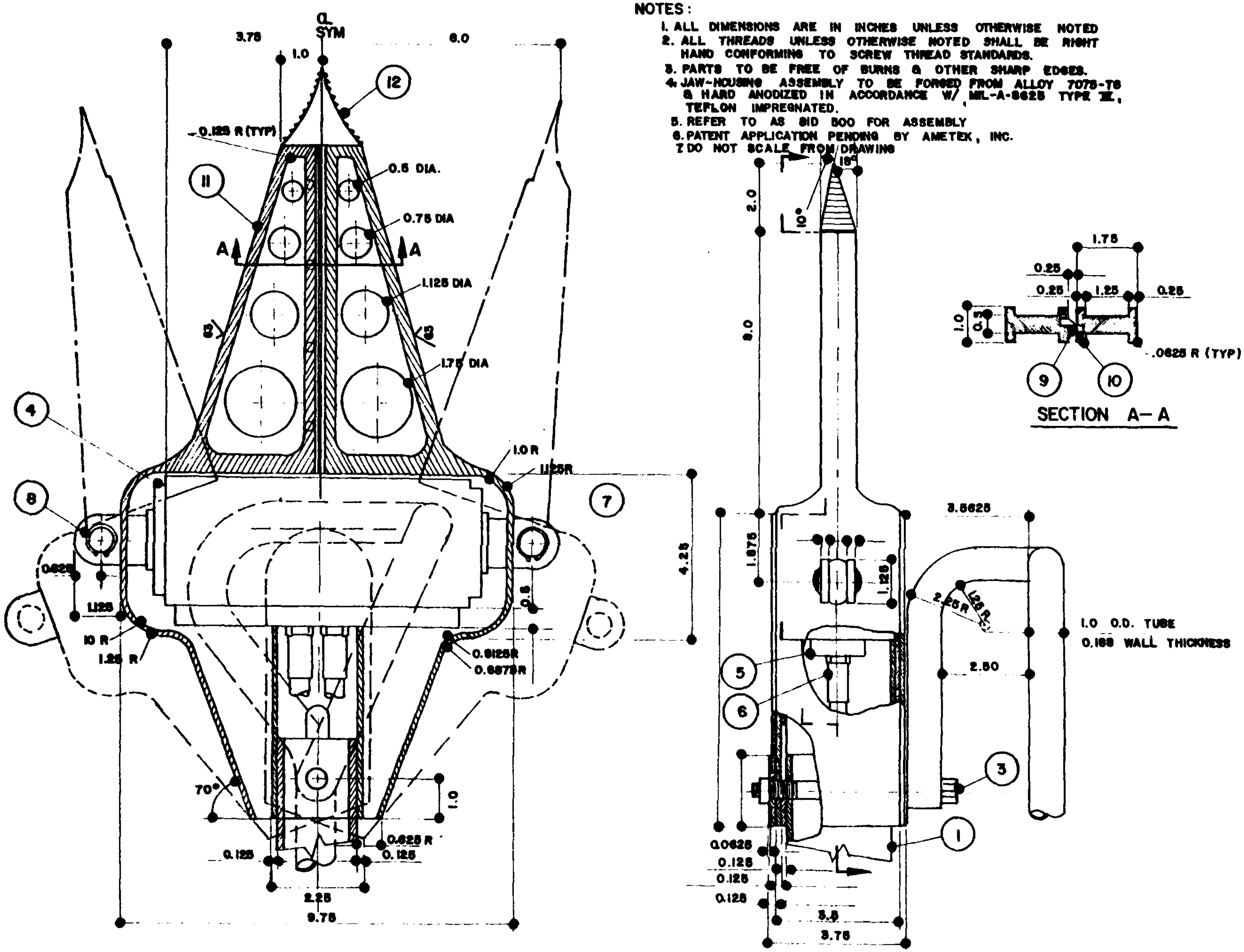
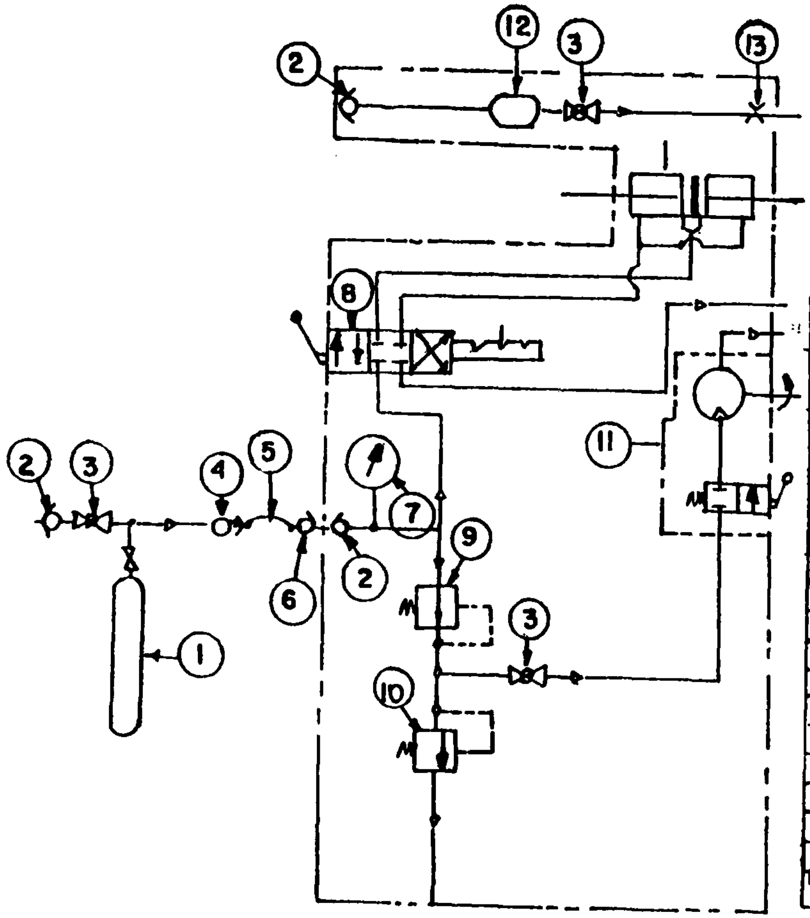


Figure 25. AMETEK Aircraft Rescue Tool Assembly



INDEX NO.	PART NO	NO. REQ.	DESCRIPTION
13	LEE	1	ORIFICE
12	AMETEK	1	RESERVOIR FOR HALON. 12H
11	INGERSOLL RAND	1	ROUTER, 125 PSI-WP, 25,000RPM, 1 - HP
10	CIRCIE SEAL	1	VALVE, PRESSURE RELIEF 3000PSI RATED PRESSURE
9	GROVE	1	VALVE, PRESSURE REDUCING 3000 PSI RATED PRESS.
8	TELEDYNE/REP	1	VALVE 4-WAY 3 POSITION 3000 PSI RATED PRESSURE
7	U.S. GAUGE	1	GAUGE PRESSURE 0-3000 PSI RANGE
6	SNAP-TITE	1	QUICK DISCONNECT, VALVED NIPPLE, CRESS
5	AEROQUIP	AR	HOSE, HEX 3,000 PSI - WP
4	NAROLLA	1	FLO-FUSE
3	WHITEY	2	BALL VALVE CRES 3,000PSI PRESSURE RATED
2	SNAP-TITE	3	QUICK DISCONNECT VALVED COUPLER
1	MSA or EQUIV	AR	PRESSURE CYLINDER 48CU.FT.22,000 PSI-WP

Figure 26. Pneumatic System Schematic

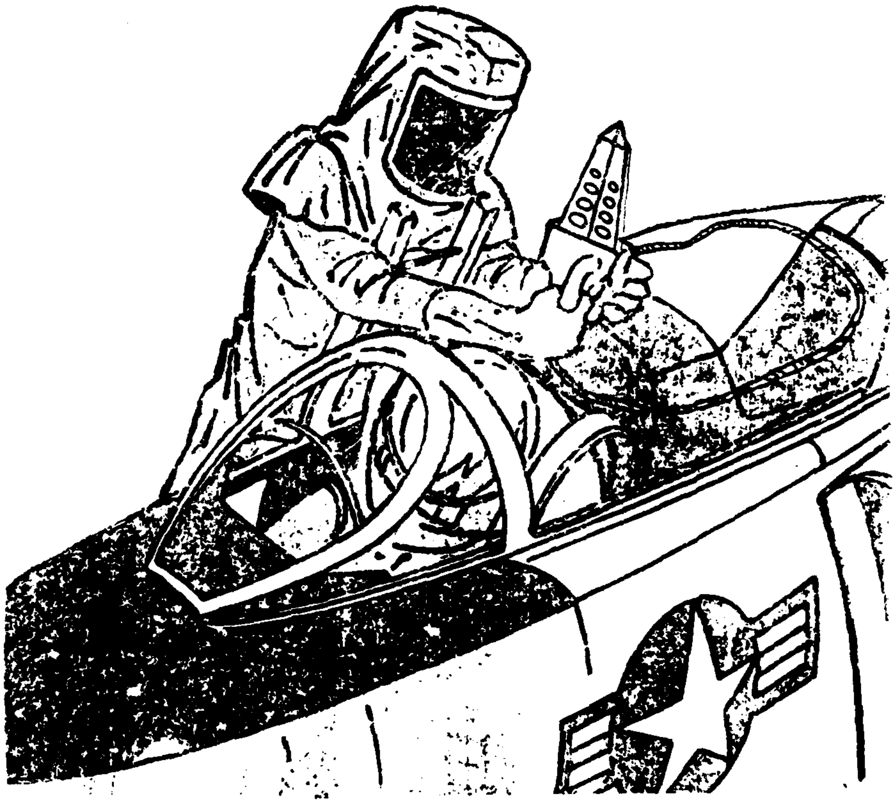


Figure 27. The AMETEK Designed Rescue Tool Making Cut Through Canopv for Rapid Rescue of Entrapped Personnel - View 1

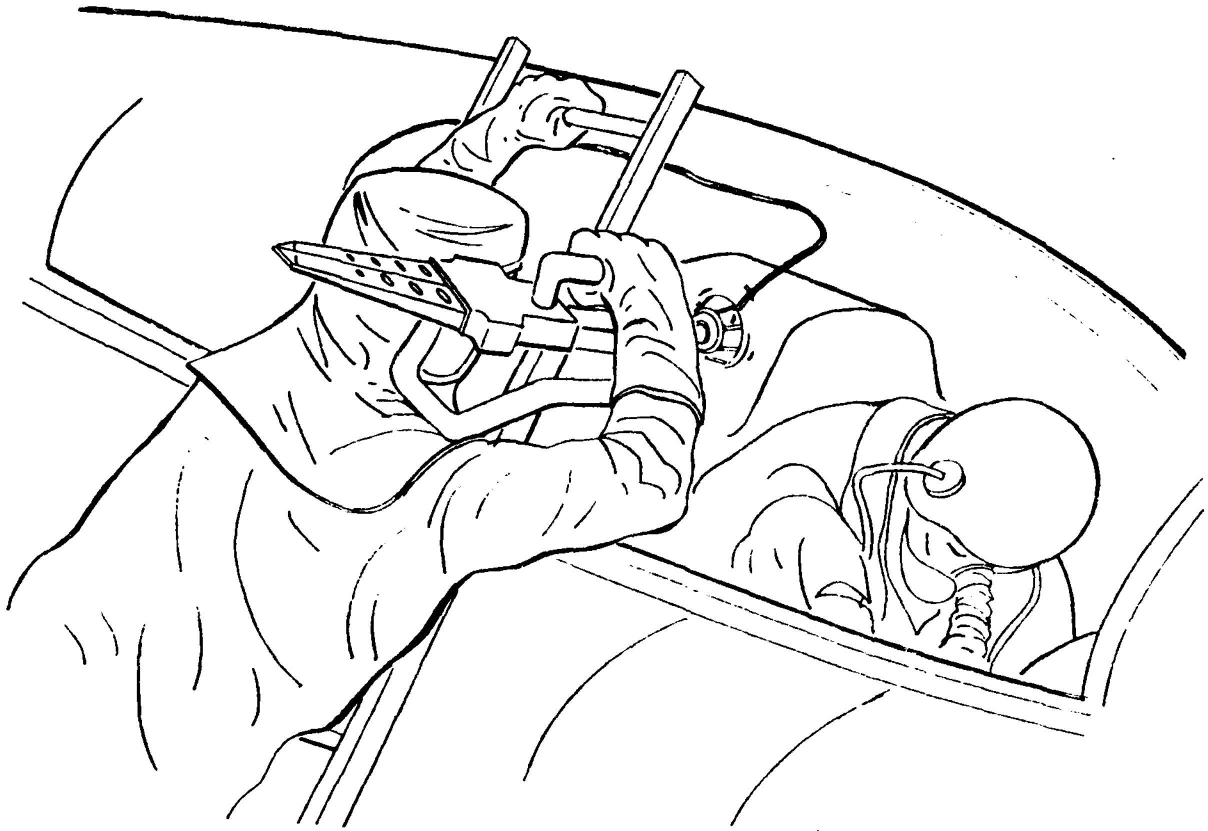


Figure 28. The AMETEK Designed Rescue Tool Making Cut Through Canopy for Rapid Rescue of Entrapped Personnel - View 2

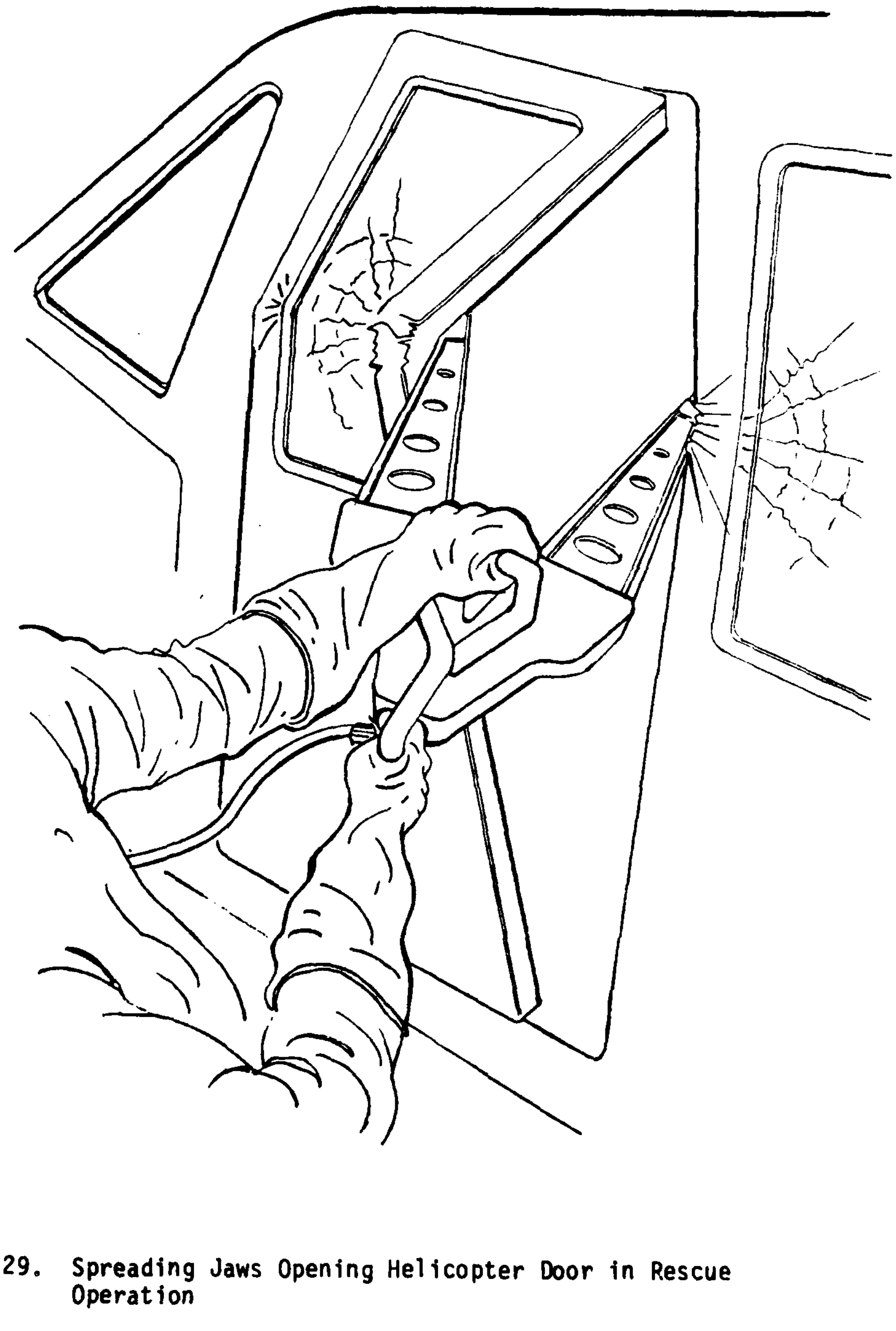


Figure 29. Spreading Jaws Opening Helicopter Door in Rescue Operation

TABLE 1. CUTTING TIMES FOR VARIOUS SAW/BLADE COMBINATIONS.

Saw	Blade Diameter	Teeth Per Inch	Operator	Cutting Fluid	Single Blade	Double Blade	Cutting Time (Seconds) Trial 1	2	3	Average
Reciprocating Air Saw (1600 strokes Per Minute)		18	M	None	X		32	22	23	26
Reciprocating Air Saw (1600 strokes Per Minute)		32	M		X		84	71	67	74
Circular Saw Abrasive Blade	6		M		X		10	-	-	10
Circular Saw Abrasive Blade	8		M		X		20	17	17	18
Circular Saw Abrasive Blade	8		M	Water	X		22	42	35	33
150-Tooth Blade	8		M	None	X		35	15	15	22
Carbidogrit-Coated Blade	7		M	None	X		14	14	15	14

Note: Material cut in all tests was 1/2" standard wall metal water pipe.

TABLE 1. CUTTING TIMES FOR VARIOUS SAW/BLADE COMBINATIONS (CONTINUED).

Saw	Blade Diameter	Teeth Per Inch	Operator	Cutting Fluid	Single Blade	Double Blade	Cutting Time (Seconds) Trial 1	2	3	Average
Carbidogrit-Coated Blade	7		M	Water	X		45 Partial Cut	40 Partial Cut	40 Very Hard Push	
12" Hacksaw		32	M	None	X		21	33	32	29
			R		X		35	43	35	38
			M			X	38	48	47	44
			R			X	65	60	64	63
			M			Blades Opposing	48	65	72	62
			R			Blades Opposing	71	74	62	69
		18	M		X		30	19	18	22

Note: Material cut in all tests was 1/2" standard wall metal water pipe.

TABLE 1. CUTTING TIMES FOR VARIOUS SAW/BLADE COMBINATIONS (CONCLUDED)

Saw	Blade Diameter	Teeth Per Inch	Operator	Cutting Fluid	Single Blade	Double Blade	Cutting Time (Seconds) Trial 1	2	3	Average
Hacksaw Gas Jet Between Blades Effective Blade Length 6 1/4"		32	M			X	140	60	85	95
Electric Sawzall (250 Strokes Per Minute)		18	M			X	180	175	200	185
Reciprocating Air Saw (1600 Strokes Per Minute)		18	M		X	X	32	22	23	26
		32	M		X		84	71	67	74

Note: Material cut in all tests was 1/2" standard wall metal water pipe.

TABLE 2. RISK ASSESSMENT - SAFE OPERATION IN A FLAMMABLE ENVIRONMENT.

Case	Description	Concept For Safe Cutting	Risk For Plastic	Alum	Mag	Ti	Steel	Glancing Contact to Steel
First instance of tool penetration through panel	Tool point emerges through panel to inside zone	Emerging point has zero peripheral velocity and will not generate friction sparks Halon 1211 cutting fluid emerges through space between cutting edges cooling surfaces	None	None	None	None	None	Low
		Halon 1211 creates protective envelope						
	A burr lip is turned inward as tool emerges	Halon 1211 cutting fluid emerges through cutting tool cooling the inward turning burr or chip Halon 1211 creates protective envelope Emerging tool point has very low peripheral velocity due to conical shape	None	None	None	None	None	Low
	Halon 1211 supply fails as point emerges through panel	Zero to low peripheral velocity of tool point	None	None	None	None	None	Low

TABLE 2. RISK ASSESSMENT - SAFE OPERATION IN A FLAMMABLE ENVIRONMENT (CONTINUED).

Case	Description	Concept For Safe Cutting	Risk For Plastic	Alum	Mag	Ti	Steel	Glancing Contact to Steel
Traverse Cutting	Tool is being advanced to create opening	Halon 1211 cutting fluid lubricates and cools cutting chips Halon 1211 creates protective envelope Cutting speed is low (compared to circular saw) Brush Barrier contains and directs Halon barrier Cutting tool is designed for minimal friction spark propensity Tool feed force is limited to direct manual force without mechanical advantage in the feed	None	None	None	None	Low	Low
Displacing tool	Displacing jaws opening, pushing metal outwards	Pneumatic system, no spark propensity	None	None	None	None	None	None

TABLE 2. RISK ASSESSMENT - SAFE OPERATION IN A FLAMMABLE ENVIRONMENT (CONCLUDED)

Case	Description	Concept For Safe Cutting	Risk For Plastic	Risk For Alum	Risk For Mag	Risk For Ti	Risk For Steel	Risk For Glancing Contact to Steel
	Pierce point on jaws used to pierce entry hole by hand impacting tool against panel	Plastic slip over cap on jaw tip captures any friction sparks against the surface	-	None	None	None	Low	Low

REFERENCES

1. Baumeister, Theodore, Ed., Mark's Standard Handbook For Mechanical Engineers, 8th Edition, McGraw Hill, New York, 1978.

2. Beach, Robin, "Preventing Static-Electric Fires," Chemical Engineering, 21 December 1964, 4 January 1965, 1 February 1965.

3. Bolz, Ray E., and George L. Tuve, Ed., CRC Handbook of Tables For Applied Engineering Science, 2nd Edition, CRC Press, Inc., Boca Raton, Florida, 1979.

4. Brink, E. C., "Fire Resistant Hydraulic Fluids," Lubrication, October-December, 1957, pp. 77-96.

5. Campbell, John A., "Friction Spark Ignition in Crash Fires," Quarterly of the National Fire Prevention Association, October, 1957, pp. 123-133.

6. "Cool Tip . . . Not Chip, With CO_2," American Machinist, February 15, 1954.

7. Giles, Ronald V., Fluid Mechanics And Hydraulics, 2nd Edition, Schaum's Outline Series, McGraw-Hill, New York, 1962.

8. International Civil Aviation Organization, Aerodrome Fire Services Personnel Training Manual; Part E-2, Montreal, 1976.

9. International Civil Aviation Organization, Airport Services Manual, Part 1, Rescue and Firefighting, Montreal, 1977.

10. National Fire Protection Association, Fire Officer's Guide To Fire Apparatus Maintenance, Boston, 1975.

11. International Fire Service Training Association, Aircraft Fire Protection And Rescue Procedures, 2nd Edition, Oklahoma State University, 1978.

12. International Fire Service Training Association, Essentials of Firefighting, 1st Edition, Oklahoma State University, 1977.

13. International Fire Service Training Association, Introduction To Fire Apparatus Practices, 6th Edition, Oklahoma State University, 1980.

14. Lauterbach, W. E., and E. A. Ratzel, "An Investigation Of The Flow And Effect Of A Cutting Oil In Machine Operations," Lubrication Engineering, February, 1951, pp. 15-19.

15. National Aeronautics and Space Administration Technical Brief, Penetrating Fire Extinguisher, Vol. 3, No. 3.

16. National Fire Protection Association, Fire Protection Handbook, Boston, 1980.

17. Horton, H. L., F. D. Jones, and Erik Oberg, Machinery's Handbook, 21st Edition, Industrial Press, Inc., New York, 1979.

18. Sperry-Vickers Corporation, Industrial Hydraulics Manual, Sperry-Rand Corporation, Troy, Michigan, 1970.

19. Taschorn, Gerhart, Spark Atlas of Steels, McMillan, New York, 1963.

20. U.S. Air Force, Aircraft Emergency Rescue Information (Fire Protection), Washington, DC, 1978.

21. U.S. Department of Defense, Human Engineering Design Criteria For Military Systems, Equipment And Facilities (MILSTD 1472B), U.S. Government Printing Office, Washington, DC, 1975.

22. U.S. Department of Transportation, Federal Aviation Administration, Advisory Circular, Aircraft Data, Washington, DC, 1975.

23. U.S. Department of Transportation, Federal Aviation Administration, Advisory Circular, Aircraft Fire And Rescue Facilities And Extinguishing Agents, Washington, DC, 1973.

24. U.S. Department of Transportation, Federal Aviation Administration, Advisory Circular, Fire And Rescue Service For Certified Airports, 1972.

25. Cohen, Bert M., and John A. Campbell, Minimum Needs For Airport Firefighting And Rescue Service, U.S. Department of Transportation, Federal Aviation Administration, Washington, DC, 1971.

26. Ruggles, Bertrand, A Review Of Certified Airport Crash Fire Rescue Service Criteria, U.S. Department of Transportation, Federal Aviation Administration, Washington, DC, 1978.

27. Weast, Robert C., Ed., CRC Handbook Of Chemistry And Physics, CRC Press, Inc., Boca Raton, Florida, 1979.

28. National Fire Protection Association, Halogenated Extinguishing Agent Systems Halon 1211, NFPA 12B, Boston, July, 1977.

APPENDIX A

STATE-OF-THE-ART SURVEY

(The reverse of this page is blank.)

SECTION A-1

INTRODUCTION

Over the years, progress has been made in the development of better rescue methods for personnel entrapped in damaged aircraft. Since the days of the fire axe and crowbar, a variety of special purpose tools has been introduced for cutting, prying and opening. The majority of these have been single purpose tools, necessitating time consuming changes to different tools specialized to each type of operation. In addition, the tools have been bulky and difficult to handle in confined spaces, and in some instances have generated sparks and high temperatures unacceptable in environments with NFPA Class I Flammable Liquids.

Recognizing the need to further enhance the rescue of entrapped personnel, the United States Air Force is seeking a new and better composite multiuse tool. This state-of-the-art survey was prepared in support of this objective.

SECTION A-2

RESCUE TOOLS CLASSIFICATION

Rescue tools now available have a diversity of functions and capabilities and are manufactured in a wide range of sizes. Capabilities include spreading, cutting, sawing, prying, shearing, chiseling, wedging, pulling, lifting, drilling, and piercing.

The tool functions were reviewed and grouped, and a function classification was established for this study. The classification is shown in the following flow chart of rescue functions (Figure A-1). All tool functions are described as either cutting or displacing.

Displacing functions include spreading, prying, wedging, pulling, pushing, and levering. The general intent for rescue purposes is to create an opening large enough for egress of personnel, or for access to assist in egress of personnel.

Cutting includes sawing, chiseling, axing, piercing and shearing, or may involve metal removal in the form of chips, as in sawing or grinding. Cutting may involve sawing or grinding without removal of chips, as in shearing or tearing. Cutting also may involve metal bending or folding following an initial separation, as in piercing or axing. Cutting may be done sequentially with displacing. In such cases, the cutting function would create a point of entry for a displacing tool.

Tables A-1, A-2, and A-3 list comparative features of spreading tools by spread distance, spreading force, and weights, respectively. Tables A-4 through A-5 list comparative features of prybars, axes, and come-a-longs, respectively. Tables A-7 through A-17 respectively list comparative features of circular saws (rpms, and weight-to-power ratios), reciprocating saws (stroke length, and weight-to-power ratios), panel saws (weights, and blade diameters), routers (power-to-weight ratios), drills (weight-to-power ratios), chisel material (capacity-to-weight ratios), and power hammers (power-to-weight ratios, and power). Table A-18 compares power shear cutting forces.

NOTE: Tools such as cutting torches are not considered to be viable tools for rescue of personnel and are not included in this study. Various ancillary items, such as cribbing and protective blankets, while important to rescue operations, are also excluded from this study.

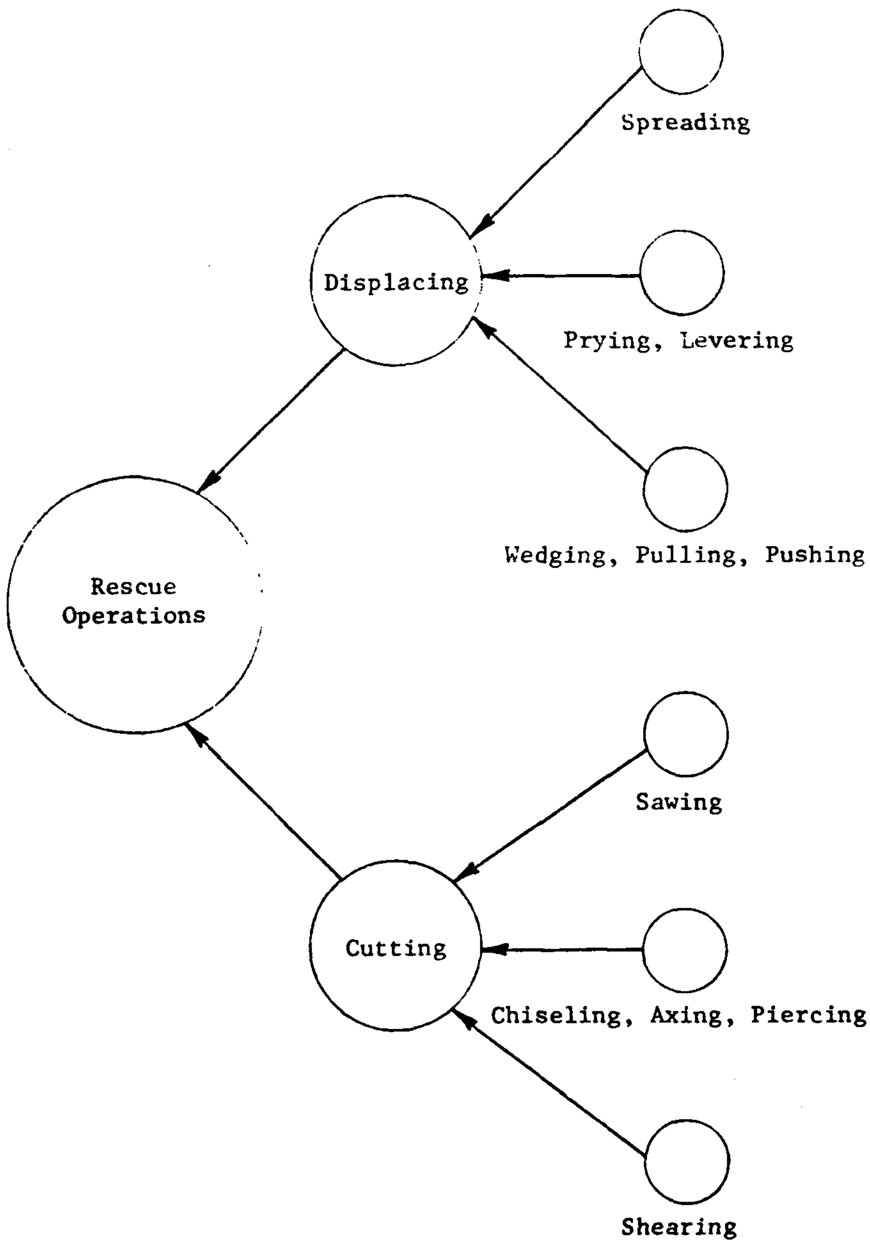


Figure A-1. Rescue Functions Flow Chart.

SECTION A-3

TOOLS FOR DISPLACING

A-3.1 COMPARATIVE SUMMARY OF SPREADING TOOL FEATURES

A-3.1.1 Spreading Distance

The Hurst 32A Hydraulic jaws had a maximum spread of 32 inches - the greatest spread of all units surveyed. The Enerpac WR15 with a maximum spread distance of 11.5 inches and a minimum spread distance of 1.25 inches had the greatest spread for units weighing less than 25 pounds. Enerpac WR4 and WR6 had the greatest spreading distance per pound of tool weight, and their spread distance varied between a maximum of 0.38 inch and a maximum of 3.75 inches; both tools weigh less than 4 pounds each.

TABLE A-1. COMPARATIVE FEATURES OF SPREADING TOOLS - SPREAD DISTANCE

TOOL	SPREAD DISTANCE (IN)	TOOL WEIGHT (LBS)	SPREADING DISTANCE/ TOOL WEIGHT IN/LB
HURST 32A	0.50-32.0	65.0	0.49
Hurst 28	0.50-28.0	69.0	0.40
Lukas 44A	0.50-27.5	47.0	0.63
HRT 26"	0.50-26.0	57.0	0.46
Hurst 12	0.50-12.0	37.5	0.32
Enerpac WR15	1.25-11.5	20.0	0.51
HRT 8"	0.50-8.0	44.0	0.18
Enerpac A-92 w/RC 106	1.38-6.25	18.25	0.27
Enerpac WR4	0.38-3.75	4.0	0.84
Enerpac WR6	0.38-3.75	3.0	0.84

Note: See Appendix F for supplier names and addresses

A-3.1.2 Spreading Force

Of units surveyed, the Hurst 32A Hydraulic Jaws unit had the maximum spreading force of 12,000 pounds at the tip, and weighed 65 pounds. The Enerpac WR6 had the maximum spreading force per pound of tool weight, with a spreading force of 1500 pounds at the tip. The Enerpac WR15, with a spreading force of 3000 pounds, had the maximum spreading force of units surveyed weighing less than 25 pounds.

TABLE A-2. COMPARATIVE FEATURES OF SPREADING TOOLS - SPREADING FORCE

TOOL	SPREADING FORCE (LBS)	TOOL WEIGHT (LBS)	SPREADING FORCE/ TOOL WEIGHT (LBS/LB)
Hurst 32A	12000	65.0	184
Hurst 28	12000	69.0	174
HRT 8"	11000	44.0	250
HRT 26"	10340	57.0	181
Hurst 12	10000	37.5	267
Lukas 44A	10000	47.0	227
Enerpac WR15	3000	20.0	150
Enerpac A-92 w/RC 106	2000	18.25	110
Enerpac WR4	1500	4.0	375
Enerpac WR6	1500	3.0	500

A-3.1.3 Weights

Of the seven hydraulic jaw units surveyed, four units weighed less than 25 pounds. The lightest of these was the Enerpac WR6, which weighs less than 3 pounds. The Enerpac WR6 was also the most inexpensive unit surveyed, costing approximately $60.00. The Enerpac WR4 had the least cost per pound of spreading force. This unit weighs under 4 pounds and has 1500 pounds of spreading force at the tip.

TABLE A-3. COMPARATIVE FEATURES OF SPREADING TOOLS - WEIGHTS

TOOL	TOOL WEIGHT (LBS)	TOTAL COST ($)	COST PER LB OF TOOL WEIGHT ($/LB)	COST PER LB OF SPREADING FORCE ($/LB)	COST PER INCH OF SPREAD DISTANCE ($/IN)
Enerpac WR6	3.0	62	20.88	0.041	18.37
Enerpac WR4	4.0	58	14.67	0.039	17.19
Enerpac A-92	18.25	159	8.71	0.080	32.62
Enerpac WR15	20.0	192	9.60	0.064	18.73
Hurst 12	37.5	3324	88.64	0.330	277.00
HRT 8"	44.0	1695	38.42	0.154	211.88
Lukas 44A	44.0	N/A	N/A	N/A	N/A
HRT 26"	57.0	3845	67.46	0.372	139.82
Hurst 32A	65.0	5573	85.74	0.45	174.16
Hurst 28	69.0	4533	65.70	0.38	164.84

Note: Tool costs represent published list prices and do not include original equipment manufacturer (OEM) or large user discounts. Costs are for comparison purposes only and represent Fourth Quarter 1980 levels.

A-3.2 COMPARATIVE SUMMARY OF PRY BAR FEATURES

A-3.2.1 Weights

The greatest weight per unit length is found in the Zico Mini-Quik bar at 6 inches per pound. The lowest was found in the Super Ram Bar in its extended position at 1.8 inches per pound.

TABLE A-4. COMPARATIVE FEATURES OF PRY BARS

TOOL	WEIGHT PER UNIT LENGTH (IN/LB)	WEIGHT (LBS)	NUMBER OF FUNCTIONS	LENGTH (IN)
Zico Mini-Quik Bar	6.0	2.0	4	12
Pry Axe	4.1-2.7	7.0	4	18.5-28.5
Forcible Entry Bar	3.8	11.0	4	42
Zico Quik Bar	3.75	8.0	4	30
Hooligan Tool iii	3.5	12.0	3	42
ii	3.3	11.0	3	36
i	3.0	10.0	3	30
Holmes K-Bar-T	3-21	17.63	3	37.25-53.5
Super Rambar	2.6-1.8	18.0	2	33-47
Crowbar 24"	N/A	N/A	2	24
36"	N/A	N/A	2	36
Pinch Point Crowbar	N/A	N/A	1	51

A-3.3 COMPARATIVE SUMMARY OF AXE FEATURES

A-3.3.1 Weights

The Sierra GlasAx is the lightest surveyed at 1.5 pounds. Other axes range to 13 pounds.

TABLE A-5. COMPARATIVE FEATURES OF AXES

TOOL	WEIGHT (LBS)	COST ($)	LENGTH (IN)
Sierra GlasAx	1.5	18.50	N/A
Atlas #4430 and 4630 Crash Axe	2.5	38.80	15
Fireman's Axe	4.5	36.95	36
	6.0	41.00	36
Partner Pry-Axe F2	7.0	77.00	18.5-28.5
Fireman's Axe	8.0	57.55	36
Atlas #4530 Crash Axe	13.0	N/A	15

A-3.4 COMPARATIVE SUMMARY OF COME-A-LONG FEATURES

A-3.4.1 Lifting Capacity

The 3-ton CM puller has the greatest lifting capacity at 3 tons. Other models range down to 1.5 tons.

TABLE A-6. COMPARATIVE FEATURES OF COME-A-LONGS

TOOL	LIFT CAPACITY (TONS)	CHAIN LENGTH (FT)	WEIGHT (LBS)
CM Puller, 3-ton	3.0	11.25	N/A
Heavy-Duty Come-a-long set	2.0	20 (cable)	N/A
CM Pull, 1-ton	1.5	5.5	24

A-3.5 SUMMARY OF DISPLACING TOOL CAPABILITIES

A-3.5.1 Spreading Tools

The HRT 8" exerts 11,000 pounds of force. Pounds of force for other tools surveyed ranged to 1500 pounds. Weights ranged from less than 3 pounds to over 69 pounds. Force per pound of weight ranged from 110 to 500 pounds. Spreading distance ranged from 3.75 inches to 28 inches.

A-3.5.2 Pry Bars

The Zico Mini-Quik Bar had the least weight-per-unit length of all pry bars surveyed. This bar is 12 inches long and performs four different operations (pike, wedge, hammer, and claw). The pry axe had the least weight per unit length of all extendable pry bars surveyed. It performs four operations, weighs 7 pounds, and its spread varies from 18.5 inches closed, to 28.5 inches open.

A-3.5.3 Axes

The Sierra GlasAx is the lightest of all axes surveyed, and also the least expensive. The Atlas #4430 Crash Axe is the heaviest of all axes surveyed. The Partner Pry-Axe F-2 is the only extendable axe surveyed.

A-3.5.4 Come-a-Longs

Come-a-longs, also known as chain or cable hoists, are manually powered. They are tension-force-producing, well suited for applications where pressure points are somewhat far apart. Load capacity of the surveyed come-a-longs ranged from 1.5 tons to 3 tons. Chain (or cable) length varied from 5.5 feet to 20 feet.

A-3.6 DESCRIPTIONS OF DISPLACING TOOLS

A-3.6.1 Spreading Tools

A-3.6.1.1 HRT 8". This unit is a smaller version of the HRT 26" spreader. It operates at 10,000 psi, has a spreading force of 11,000 pounds, has an 8-inch tip travel, and weighs 44 pounds complete with hoses.

A-3.6.1.2 Enerpac A-92 w/RC 106. Manufactured by Enerpac Applied Power, this "duck-bill" spreader has a 2000-pound capacity on lifting pads. When closed, the tip is 1.38 inches high. The maximum spread distance is 6.25 inches. When used with cylinder RC-108, and a working pressure of 8.960 psi, it weighs less than 18.25 pounds. Spring-loaded jaws automatically return when the pump valve opens.

A-3.6.1.3 Enerpac WR15. With a 3000-pound capacity, this unit produces the greatest force of all Enerpac spreaders. The tip is 1.25 inches high

when closed, and opens to 11.5 inches. Spring-loaded jaws automatically return when the pump valve opens. This unit weighs less than 20 pounds.

A-3.6.1.4 Enerpac WR6. The Wedgie is 2 inches wide, 6.5 inches long and 2 inches high. It exerts 1500 pounds of force. Its jaws can slip into a 0.38-inch clearance, can open to 3.75 inches, and are spring loaded to close automatically when the pump valve opens. This unit weighs less than 4 pounds.

A-3.6.1.5 Enerpac WR4. This unit is the same as the Enerpac WR6, but equipped with a .375-inch port pump and hose, instead of a .25-inch pump and hose.

A-3.6.1.6 Lukas 44A. Made by Lukas Rescue Systems, the Lukas 44A operates from a 9,700 psi hydraulic pump. The spreading force at the tip is 10,000 pounds. The closing power is also 10,000 pounds. The tip spread distance is 27.5 inches with tips reversed. This unit weighs 44 pounds.

A-3.6.1.7 HRT 26". From Paratech, Incorporated, this hydraulic unit operates at 19,500 psi. The spreading force at the tip is 10,340 pounds. The closing power is 7,700 pounds. The tip spread distance is 26 inches, and this unit weighs 57 pounds, including the hoses.

A-3.6.1.8 Hurst 32A. This 65-pound "jaws of life" has a 32-inch spread distance, the maximum spread distance of all tools surveyed. Arms open in 15 seconds without load and 50 seconds under load. It operates with a maximum output of 12,000 pounds of force at the tips of the jaws.

A-3.6.1.9 Hurst 28. A scaled-down version of the Hurst 32A, this unit weighs 69 pounds and has a spread distance of 27.5 inches. Arms open in 15 seconds without load and 50 seconds under load. It operates with a maximum output of 12,000 pounds of force at the tips of the jaws.

A-3.6.1.10 Hurst 12. The lightest of the Hurst tools, the unit weighs 37.5 pounds and has a spread distance of 12 inches. Arms open in 5 seconds without load and 16 seconds under load, and it operates with a maximum output of 10,000 pounds of force at the tips of the jaws.

A-3.6.2 Pry Bars

A-3.6.2.1 Pry Axe F-2. This tool, constructed of high alloy forged steel, is extendable - minimum length 18.5 inches, maximum length 28.5 inches. One end of the tool is a slotted claw which doubles as a gas shutoff. The other end is a combination axe blade with serrated teeth and pike. The shaft has an insulated handle and the claw has a quick release. Overall weight is 7 pounds.

A-3.6.2.2 Forcible Entry Bar F-1. The F-1 is four-function, 42-inch multipurpose pry bar. One end of the tool operates as a pry bar, the other as a pike wedge. Constructed of forged steel, it weighs 11 pounds.

A-3.6.2.3 Hooligan Tool. Manufactured by Paratech, Incorporated, this tool is available in three sizes: 30 inches, 36 inches, and 42 inches. The respective weights are 10 pounds, 11 pounds, and 12 pounds. One end of this tool is a slotted claw which fits hasps, locks, latches, and gas shut-offs. The other end is a combination duckbill and pick. The bar is tempered steel and press-fitted to either end.

A-3.6.2.4 Super Rambar. This forcible entry tool uses the sliding ram principle. It is 33 inches closed and the ram travel is 14 inches. Overall weight is 18 pounds. It is made of high alloy steel, and heat treated with a slip prod grip. The Super Rambar can also be used to shut off gas lines and remove hasps.

A-3.6.2.5 Crowbar. Made of drop-forged steel, this bar is available in two lengths: 24 inches and 36 inches. One end consists of a chisel, the other is a hooked claw.

A-3.6.2.6 Pinch Point Crowbar. This 51-inch, steel bar conforms to Underwriter's specifications.

A-3.6.2.7 Quik Bar. This tool, Model QBC, is a 30-inch, drop-forged, steel alloy, forced-entry rescue tool. One end of the tool is a slotted claw which doubles as a gas shutoff. The other end is a combination wedge and pike.

A-3.6.2.8 Mini-Quik Bar. The Mini-Quik Bar is identical to the Quik Bar in construction and function, but is only 12 inches long.

A-3.6.2.9 Quik K-Bar-T. Made by Fiamatic, Model K-B-T, this tool extends from 37.25 inches to 53.5 inches. It comprises three tools: impact slide hammer, chisel, and cutting blade. The total weight of this tool, including case, is 17.63 pounds.

A-3.6.3 <u>Axes</u>

A-3.6.3.1 Sierra GlasAx. This tool has a 1.25-pound treated, forged-steel serrated head mounted on a fiberglass handle. The head is bonded to the handle with epoxy. The total weight of this tool is 1.5 pounds.

A-3.6.3.2 Atlas Crash Axe. The Atlas No. 4430 and No. 4630 serrated Crash axes, are manufactured to U.S. Government specifications: one-piece drop-forged steel, steel handle, and rubber insulated for 20,000 volts. These axes weigh approximately 2.5 pounds. Overall length is 15 inches.

A-3.6.3.3 Fireman's Axe. This is a pickhead axe with a 36-inch fiberglass handle. Axe heads are available with weights of 4.5, 6, or 8 pounds.

A-3.6.3.4 Partner Pry-Axe F-2. This is an alloy steel axe with an extendable handle (18.5 to 28.5 inches).

A-3.6.3.5 Axes. This tool comprises a pike, axe blade, serrated blade, claw, and gas shutoff. The handle is insulated. Overall weight is 7 pounds.

A-3.6.4 Come-a-Longs

A-3.6.4.1 CM Puller, 3 Ton. The 3-ton CM Puller is a chain hoist of aluminum alloy. It is weatherized and ruggedly built.

A-3.6.4.2 CM Puller, 1.5 Ton. The 1.5-ton CM Puller is a smaller version of the 3-ton CM Puller, sharing construction methods and materials. By reducing the lift capacity to 1.5 tons, the weight of the tool is kept to 24 pounds.

A-3.6.4.3 Heavy Duty Come-a-Long Set. This is a 2-ton cable hoist, built for rescue work. This tool uses a hook and block to increase lift capacity and reduce required force input.

SECTION A-4

TOOLS FOR CUTTING

A-4.1 COMPARATIVE SUMMARY OF CIRCULAR SAW FEATURES

A-4.1.1 RPMs

Of all circular saws surveyed, the Partner K1200 has the highest blade speed at 6000 rpms. The lowest speed of the tools surveyed was 4000 rpms, and was from the Stanley line. These speeds are in the rpm range for abrasive cutting.

TABLE A-7. COMPARISON OF CIRCULAR SAW FEATURES - RPMS

TOOL		BLADE SPEED (RPM)	MAXIMUM CUTTING DEPTH (IN)	POWER (HP)
Partner K1200		6000	4.8	5.4
Homelite DM50		5750	4.0	4.0
DM20		5500	4.0	3.1
XL98A		5250	4.0	4.7
Thor 6015		5100	N/A	3.6
Partner K65		5100	4.0	3.8
Black & Decker	3912	5000	4.0	2.0
	3052	4300	2.84	1.75
Stanley 6008		4000	N/A	8.0
6023		4000	N/A	N/A
Target Quickie	5714 612	N/A	4.0	4.5
	5714 616	N/A	4.0	6.5
	5714 616	N/A	5.0	6.5
	Electric	N/A	4.0	2.75

A-4.1.2 Weight-to-Power Ratio

The lowest weight-to-power ratio is found in the Amfire Water Saw at 1.75 pounds per horsepower. This is also a comparatively light saw (21 pounds). The Stanley 6008 is very close in weight-to-power ratio (2 pounds per horsepower) and weighs 5 pounds less. Most of the saws have a similar maximum cutting depth of 4 to 5 inches.

TABLE A-8. COMPARISON OF CIRCULAR SAW FEATURES - WEIGHT-TO-POWER RATIO

TOOL		WEIGHT-TO-RATIO (LB/HP)	WEIGHT (LBS)	MAXIMUM CUTTING DEPTH (IN)
Amfire Water Saw		1.75	21	N/A
Stanley	6008	2.0	16	N/A
Target Quickie	5714 616	4.6	29.75	5.0
	5714 612	4.6	29.75	4.0
	5714 608	4.8	21.75	4.0
Homelite	XL98A	5.5	26	4.0
Partner	K1200	5.7	31.9	4.8
	K65	6.7	25.6	4.0
Thor	6015	6.9	25	N/A
Homelite	DM50	7.0	28	4.0
	DM20	7.75	24	4.0
Black & Decker	3052	7.6	16.75	2.84
Target & Quickie Electric		13.0	26	4.0
Black & Decker	3912	13.5	27.5	4.0
Stanley	6023	N/A	19	N/A

A-4.2 COMPARATIVE SUMMARY OF RECIPROCATING SAW FEATURES

A-4.2.1 Stroke Length

Of all reciprocating saw features surveyed, the Rockwell 52Z-510 has the longest stroke length at 3 inches. Other strokes range down to 0.63 inch for the Ingersoll-Rand SRA010A1. Stroke rates in the Widder and Rockwell tools are 320 to 350 strokes per minute. Black & Decker and Ingersoll-Rand both use much faster rates (1000 to 3100 strokes per minute).

TABLE A-9. COMPARISON OF RECIPROCATING SAW FEATURES - STROKE LENGTH

TOOL		STROKE LENGTH (IN)	WEIGHT TO POWER RATIO (LB/HP)	STROKES PER MINUTE CPM
Rockwell 52Z-510		3.0	N/A	350
Widder MOT6-20		2.41	9.4	320
AST 750		2.41	9.0	330
Black & Decker	3103-09	1.0	10.0	2200
	3157-10	1.0	20.4	3100
	3153-10	1.0	20.4	3100
	3159-10	1.0	20.4	3100
Ingersoll-Rand	SRA010A	.63	12.7	1600
Widder 18 800		N/A	N/A	320

A-4.2.2 Weight-to-Power Ratio

The Widder AST 750 has the lowest weight-to-power ratio at 9 pounds per horsepower. It is also the heaviest at 18 pounds. Some of the tools with higher ratios are light tools. An example is the Black & Decker 3103-09 with a weight-to-power ratio of 10 pounds per horsepower and a weight of 8 pounds.

TABLE A-10. COMPARISON OF RECIPROCATING SAW FEATURES - WEIGHT-TO-POWER RATIO

TOOL		WEIGHT-TO-POWER RATIO (LB/HP)	STROKE LENGTH (IN)	WEIGHT (LBS)
Widder AST 750		9.0	2.41	18.0
MOT6-20		9.4	2.41	16.0
Black & Decker 3103-09		10.4*	2.41	8.0
Ingersoll-Rand	SRA010A1	12.7	1.0	8.25
	3153-10	20.4*	0.63	6.2
	3157-10	20.4*	1.0	6.2
	3159-10	20.4*	1.0	6.2
Widder 18 800		N/A	N/A	N/A
Rockwell 52Z-510		N/A	3.0	15.5

*Estimated

A-4.3 COMPARATIVE SUMMARY OF PANEL SAW FEATURES

A-4.3.1 Weights

Of all panel saw features surveyed, the Sioux 3P1460 is the lightest at 6.75 pounds. Weights range to nearly 12 pounds (Kett K523AM and K525AM).

TABLE A-11. COMPARISON OF PANEL SAW FEATURES - WEIGHTS

TOOL		WEIGHT (LBS)	RPM	BLADE DIAMETER
Sioux	3P1460	6.75	1400	2.5
Dotco	10L4216	7.9	5800	4.0
	10L4217	7.9	7200	4.0
	10L4218	7.9	8600	4.0
Kett	KS21AM	<9.0	N/A	N/A
	KS23AM	<12.0	1400	2.0
	KS25AM	<12.0	N/A	2.5

A-4.3.2 Blade Diameters

The greatest blade diameter is from the DOTCO line at 4 inches. The Kett K525AM had the smallest blade with a 2-inch diameter.

TABLE A-12. COMPARISON OF PANEL SAW FEATURES - BLADE DIAMETERS

TOOL		BLADE DIAMETER (IN)	RPM	WEIGHT (LBS)
Dotco	10L4216	4.0	5800	7.9
	10L4217	4.0	7200	7.9
	10L4218	4.0	8600	7.9
Sioux	3P1460	2.5	1400	6.75
Kett	KS23AM	2.5	N/A	<12.0
	KS25AM	2.0	1400	<12.0
	KS25AM	N/A	N/A	<9

A-4.4 COMPARATIVE SUMMARY OF ROUTER FEATURES

A-4.4.1 Weight-to-Power Ratio

Of all router features surveyed, the lowest weight-to-power ratio is from the Sioux line of routers at 3.6 pounds per horsepower. These tools weigh 4.5 pounds. The Black & Decker 3300 and 3265 had the highest ratios at 8 pounds per horsepower.

TABLE A-13. COMPARISON OF ROUTER POWER-TO-WEIGHT RATIOS

TOOL		WEIGHT-TO-POWER RATIO (LB/HP)	WEIGHT (LBS)	ROUTERS (RPM)	POWER (HP)
Sioux 1980		3.6	4.5	20000	1.25
1981		3.6	4.5	10000	1.25
Black & Decker	3325	4.4	13.25	23000	3.00
	3310	4.8	7.25	25000	1.50
	3320	5.63	11.25	23000	2.00
Sioux 1983		6.0	7.5	20000	1.25
1984		6.0	7.5	20000	1.25
Black & Decker	3330	7.5	7.5	22000	1.00
	3300	8.0	5.0	27000	.63
	3265	8.0	5.0	27000	.63

A-4.5 COMPARATIVE SUMMARY OF DRILL FEATURES

A-4.5.1 Weight-to-Power Ratio

Of all drill features surveyed, the Ingersoll-Rand 00A23 had the lowest weight-to-power ratio at 5.33 pounds per horsepower. The Black & Decker drill had the highest weight-to-power ratio.

TABLE A-14. COMPARISON OF DRILL WEIGHT-TO-POWER RATIOS

TOOL		WEIGHT-TO-POWER RATIO (LB/HP)	WEIGHT (LB)	RPM
Black & Decker	1348	33.00	10.50	600
	1330	10.50	15.75	450
	1190-09	9.47	6.25	900
Sioux 21610		7.70	2.31	2000
Ingersoll-Rand	2XLA2	7.20	13.75	500
Sioux P1310		7.10	2.13	5200
Ingersoll-Rand	3SKA	6.38	23.00	300
	0A2N	5.63	3.94	550
	00A2J	5.53	2.00	4500
Sioux 1454		N/A	2.25	2600
Chicago Pneumatic	CP-9288-9	N/A	3.38	900
	CP-3217 PUSTU	N/A	3.50	500
	CP-3020 PUSTY	N/A	4.13	1100
	CP-0310 PASAN	N/A	8.25	925

A-4.6 COMPARATIVE SUMMARY OF POWER CHISEL FEATURES

A-4.6.1 Material Capacity-to-Weight Ratio

The Chicago Pneumatic CP4444 RUSAB and RUTAB have the greatest material capacity-to-weight ratio at 0.068 inch per pound. The Chicago Pneumatic CP44447 RUSAB and the Sioux Air Slugger 720 had the lowest material capacity-to-weight ratios at 0.039 inch per pound.

TABLE A-15. COMPARISON OF POWER CHISEL MATERIAL CAPACITY-TO-WEIGHT RATIOS

TOOL		MATERIAL CAPACITY TO WEIGHT RATIO (IN/LB)	WEIGHT (LBS)	BLOWS PER MINUTE (CYC/MIN)
Chicago Pneumatic				
CP4444 RUSAB		0.068	2.31	2160
CP4444 RUTAB		0.068	2.75	1740
Sioux Air Slugger 722		0.058	3.25	3500
Chicago Pneumatic CP9310		0.054	3.50	3300
CP4446 RUTAB		0.054	3.50	1500
CP4447 RUVAB		0.052	6.00	700
CP9316		0.050	3.75	2100
CP4447 RUTAB		0.049	5.13	1140
CP4444 RURAB		0.042	2.25	2580
CP4447 RUSAB		0.039	4.75	1560
Sioux Air Slugger 720		0.039	4.75	2000
Black & Decker	5161	N/A	3.40	3000
	5162	N/A	4.00	3000
	5164	N/A	4.00	4000

A-4.7 COMPARATIVE SUMMARY OF POWER HAMMER FEATURES

A-4.7.1 Power-to-Weight Ratio

The Black & Decker 5079-09 had the greatest power-to-weight ratio of all power hammers surveyed. This unit also had the greatest speed (rpms) and most blows per minute. It is impossible to compare the Black & Decker tools to the Chicago Pneumatic tools because of the lack of available information.

TABLE A-16. COMPARISON OF POWER HAMMER FEATURES - POWER-TO-WEIGHT RATIOS

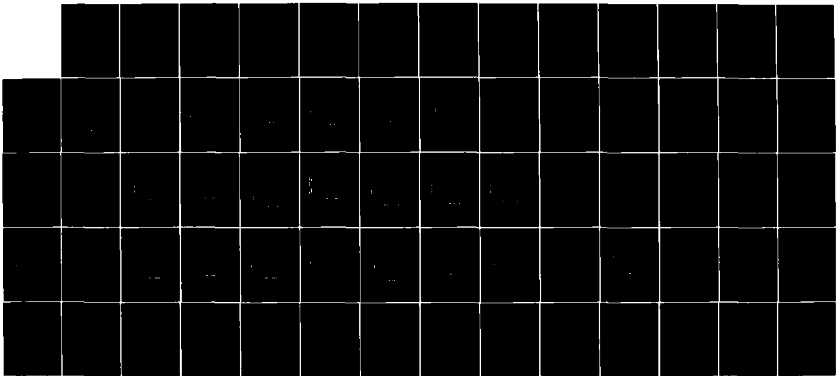
TOOL	POWER-TO-WEIGHT RATIO (WATTS/LB)	WEIGHT (LBS)	SPEED (RPM)	BLOWS PER MINUTE (CYC/MIN)
BLACK & DECKER				
5079-09	90	6.0	3400	58,000
5043-09	56	13.5	300	2,800
5042-09	54	13.0	550	2,800
5041-09	53	10.0	600	330
5026	33	63.0	0	610
5025	30	31.25	0	1,800
CHICAGO PNEUMATIC				
CP-0956 LEGAR	N/A	3.5	0	4,300
CP-0456 BEGAR	N/A	4.0	0	4,300
CP-0457 LASAR	N/A	2.75	0	5,160
CP-0458 PASAR	N/A	5.75	0	4,100
CP 9356	N/A	3.75	0	4,600
CP 9356-PH	N/A	4.0	0	4,600

A-4.7.2 Power

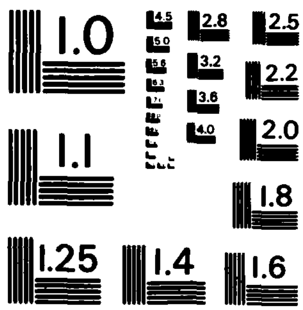
The Black & Decker 5026 has the greatest power of all power hammers surveyed. The Black & Decker 5043-09 has the greatest power of all tools weighing less than 25 pounds. It is impossible to compare the Black & Decker tools to the Chicago Pneumatic tools because of the lack of available information.

AD A124 308 DEVELOPMENT OF AN OPTIMUM RESCUE TOOL DETAILED PROTOTYPE CONCEPT DESIGN(U) AMETEK/ORED SANTA BARBARA CA R A OLSEN ET AL. JUN 81 AFESC/ESL-TR-81-28 2/2

UNCLASSIFIED F08635-80-C-0356 F/G 6/7 NL



END
DATE
FILMED
3 83
DTIC



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

TABLE A-17. COMPARISON OF POWER HAMMER FEATURES - POWER

TOOL	POWER (WATTS)	WEIGHT (POUNDS)	BLOWS PER MINUTE (CPM)
BLACK & DECKER			
5026	2050	63.0	610
5025	950	31.25	1800
5043-09	750	13.5	2800
5042-09	700	13.0	2800
5079-09	540	6.0	58000
5041-091	530	10.0	3300
CHICAGO PNEUMATIC			
CP-09561 LEGER	N/A	3.5	4300
CP-0456 BEGAR	N/A	4.0	4300
CP-0457 LASAR	N/A	2.75	5160
CP-0458 PASAR	N/A	5.75	4100
CP-9356	N/A	4.0	4600

A-4.8 COMPARATIVE SUMMARY OF POWER SHEAR FEATURES

A-4.8.1 Cutting Force

The HRT Shear model P/N 36000 had the greatest cutting force of all shears surveyed. The HK Porter model 1790 CDX had the greatest cutting force for tools weighing less than 25 pounds.

TABLE A-18. COMPARISON OF POWER SHEAR CUTTING FORCES

TOOL	CUTTING FORCE (POUNDS)	JAW CAPACITY (INCHES)	WEIGHT (POUNDS)
HRT SHEAR P/N 36000	37,000	4.5	32.0
HURST 0-90	30,000	4.0	33.0
HK PORTER 1790 CDX	25,000	3.0	18.5
HURST 0-150	25,000	6.5	36.0
ENERPAC CABLE CUTTER WCS 100	16,000	2.0	7.0
SIERRA I, II, III	13,200	4.0	22.0

A-4.9 SUMMARY OF CUTTING TOOL CAPABILITIES

A-4.9.1 Circular Saws

Following is a summary of circular saws compared during the state-of-the-art survey. Available saws use five different power sources: water, gasoline, electricity, hydraulic (oil) power, and air.

The saws have good weight-to-power ratios from 1.75 pounds per horsepower to 13.5 pounds per horsepower. The lightest circular saw weighed 16 pounds, while the heaviest weighed nearly 32 pounds.

All the saws use abrasive disks for cutting metal. These abrasive cutting disks can produce sparking when cutting steel, a hazard in some instances. Saws powered by gasoline or electricity create additional hazards. Diameter for saw blades used was 12 to 14 inches, which limited cutting depth to 4 or 5 inches.

A-4.9.2 Reciprocating Saws

Reciprocating saws weighed between 6.2 and 16 pounds. Power-to-weight was in the range of 9 to 21 pounds per horsepower.

The absolute power output of reciprocating saws is less than some other types of saws. Reciprocating saws also use a different type of cutting motion. One result of this difference in cutting motion is a large cutting depth.

Cutting rates for reciprocating saws fell into two distinct ranges: slow, at 320 to 350 strokes per minute; and moderately fast, at 1600 to 3100 strokes per minute. Power sources used in reciprocating saws included air, hydraulic power, water pressure, and electric power.

A-4.9.3 Panel Saws

Panel saws are lightweight (most less than 10 pounds). They are intended for cutting relatively thin materials – sheet steel, sheet aluminum, fiberglass, and acrylic sheet.

Panel saws typically have a small-diameter blade (2 to 4 inches) and moderate to high blade speed (1400 to 8600 rpms). Saws surveyed were either electrically or pneumatically powered.

A-4.9.4 Routers

Routers surveyed were air or electrically powered. As a class of tools, routers are distinguished by their weight (most are under 10 pounds) and blade speed (20,000 to 27,000 rpms). The weight-to-power ratio for routers ranged from 3.6 pounds per horsepower to 8 pounds per horsepower. This is a range similar to that found in circular saws.

A-4.9.5 Drills

Drill characteristics ranged widely. The weight-to-power ratio in drills varied from 5.33 pounds per horsepower to 33 pounds per horsepower. Absolute weight in the drills surveyed ranged from 2 pounds to 23 pounds. Drill speeds have a similarly wide range from 300 rpms to 5200 rpms. Power for the drills surveyed was either electric or pneumatic.

A-4.9.6 Power chisels

The weight of power chisels ranged from 2.31 pounds to 6 pounds. Frequency of blows ranged from 900 to 4000 blows per minute. Material capacity-to-weight ratio ranged from 0.039 to 0.068 inch per pound. All tools surveyed were pneumatically powered.

A-4.9.7 Power hammers

Power hammers ranged in weight from 2.75 pounds to 63 pounds. Frequency ranged from 330 to 58,000 blows per minute.

A-4.9.8 Power shears

Power shears surveyed ranged in weight from 7 pounds (less actuating cylinder) to 36 pounds. Jaw capacity ranged from 2 to 4.5 inches. The force exerted by the jaws ranged from 13,200 pounds to more than twice that of 37,000 pounds of force.

A-4.10 DESCRIPTIONS OF CUTTING TOOLS

A-4.10.1 Circular Saws

A-4.10.1.1 Amfire Water Saw. This saw is water powered, requiring 35 gpm at 200 psi. It is one part of a tool head-power unit system. Available tool heads for the Amfire Water Saw include a circular saw, a reciprocating saw, a power hammer, and a drill. The unit is capable of wet sawing and dry sawing.

A-4.10.1.2 Stanley C008 and C023. These saws are hydraulically powered circular saws which provide good power with moderate weight. They utilize Hyreuz hydraulic motors which require 7 to 9 gallons per minute at 1000 psi to 2000 psi. The C008 can utilize 12-inch or 14-inch blades while the C023 uses 14-inch blades.

A-4.10.1.3 Target Quickie Electric. This saw weighs 26 pounds, uses electric power, and is 24 inches long, 12.75 inches high and 10.75 inches wide. It uses 12-inch blades and draws 22 amperes at 115 volts.

A-4.10.1.4 Target Quickie 5714616, 571412, and 5714608. These saws are gasoline powered. The 5714608 model is medium weight at 21.75 pounds. It

uses a 12-inch blade and has a 4.5 horsepower engine. The 5714616 and 5714612 models have 6.5–horsepower gasoline engines. The 57141612 uses a 12-inch blade and the 5714616 uses a 14-inch blade. Both saws are heavy at 29.75 pounds.

A-4.10.1.5 Homelite XL98A, DM50, DM20. These gasoline-powered saws have 3.5-, 4.5-, and 5.3-cubic-inch engines, respectively, for the DM20, the DM50, and the SL984. All three models use 12-inch blades.

A-4.10.1.6 Partner K65 and K1200. The Partner K65 model has a 3.8 horsepower gasoline engine. The saw weighs 25.6 pounds. Its cutting capacity in steel (SIS1311) is 5.4 square inches per minute.

The Partner K1200 uses a 100 cc engine. Its weight is 31 to 31.9 pounds depending on blade size (12-inch or 14-inch blades may be used). Cutting capacity in steel (SIS1311) is 7.7 square inches per minute.

A-4.10.1.7 Thor 601S. The Thor 601S is a moderately heavy saw at 25 pounds. This saw is air powered and produces 3.6 horsepower. Twelve-inch blades are used.

A-4.10.2 <u>Reciprocating Saws</u>

A-4.10.2.1 Rockwell 52Z-510. The Rockwell 52Z-510 is air powered and requires 30 CFM at 90 to 100 psi. Weight is a moderate 15.5 pounds. A 3-inch stroke is utilized at a freauency of 350 stokes per minute. Maxium capacity is 14 inches in diameter at any one oosition.

A-4.10.2.2 Widder MOT6-20. This moderate weight (16 pounds) saw is air powered and requires 45 CFM at 85 psi. It has a 1.7–horsepower motor and will saw with a variable frequency of 0 to 320 strokes per minute. It uses a 2.41-inch stroke.

A-4.10.2.3 Widder AST 750. This is a 2-horsepower electric saw which uses 110 volts (220-volt motor is available). The saw cuts 330 strokes per minute and has a capability for cutting pipe to 27 inches in diameter.

A-4.10.2.4 Widder is 18-800. This saw is hydraulically powered. It develops a maximum of 2.3 horsepower. It requires 1.5 to 6 gallons per minute at 1400 to 1800 psi. Stroke rate is 25 to 320 strokes per minute, infinitely variable.

A-4.10.2.5 Black & Decker 3103-09. The Black & Decker 3103-09 is a two-speed electric saw. It cuts at 1600 or 220 strokes per minute, with a 1-inch stroke. The saw draws 6 amperes at 120 VAC. The saw is lightweight at 8 pounds.

A-4.10.2.6 Black & Decker S157-10, 3153-10, 3159-10. These are electric saws of the jigsaw type. All draw 4.5 amperes at 120 VAC. Each has a 1-inch stroke. Speed is variable from 0 to 3100 strokes per minute in the

3153-10 and the 3157-10. The 3159-10 is two-speed with speeds of 2100 and 3100 strokes per minute. The saws are lightweight at 6.5 pounds.

A-4.10.2.7 Ingersoll-Rand SRA010A1. This saw is air powered. It uses a .63-inch stroke at a rate of 1600 strokes per minute. Rated power is 0.65 horsepower. The tool is lightweight at 8.25 pounds.

A-4.10.3 Panel Saws

A-4.10.3.1 Sioux 3 P1460. The Sioux 3 P1460 is air powered and capable of cutting panels from .06-inch to .63-inch thick. Maximum power is 0.75 horsepower. Tool weight is 6.75 pounds. Blade speed is 1400 rpms. Blade diameter is 2.5 inches.

A-4.10.3.2 Dotco 10L4216, 10L4217, 10L4218. These air-powered panel saws are capable of cutting up to .75-inch thick fiberglass. Weight is 7.9 pounds. Blade speeds are 5800 rpms the 10L4216, 7200 rpms for the 10L4217, and 8600 rpms for the 10L4218.

A-4.10.3.3 Kett KS-21AM. This electrically powered panel saw uses 115 VAC/DC. It is capable of cutting aluminum to .187-inch thick and steel to 12 gauge. Weight is less than 9 pounds.

A-4.10.3.4 Kett KS-25AM. Electrically powered, this saw requires 115 VAC/DC power. Its speed is 1400 rpms, and it is capable of cutting 1-gauge steel and aluminum to .187-inch thick. Weight is less than 12 pounds.

A-4.10.3.5 Kett KS-23AM. Electrically powered, the Kett KS-23AM requires 115 VAC/DC power for a speed of 1400 rpms. Capable of cutting 16-gauge steel and aluminum to .187-inch thick, its weight is less than 12 pounds.

A-4.10.4 Routers

A-4.10.4.1 Sioux 1980, 1981, 1983, and 1984. These routers are air powered with 1.25 horsepower motors and a running speed of 20,000 rpms. The 1980 and 1981 models weigh 4.5 pounds; the 1983 and 1984 models weigh 7.5 pounds.

A-4.10.4.2 Black and Decker 3325. This 3-horsepower electric router weighs 13.25 pounds and has a running speed of 23,000 rpms.

A-4.10.4.3 Black and Decker 3310. This 1.5-horsepower electric router has a running speed of 25,000 rpms, and weighs 7.25 pounds.

A-4.10.4.4 Black and Decker 3320. This 2-horsepower electric router has a running speed of 23,000 rpms; it weighs 11.25 pounds.

A-4.10.4.5 Black and Decker 3330. This .63-horsepower electric router has a running speed of 27,000 rpms; it weighs 5.0 pounds.

A-4.10.5 Drills

A-4.10.5.1 Black and Decker 1348. This 1/2-inch electric drill has a 400-watt output at 120V. A right angle drive allows speeds of 400, 600 or 950 rpms. It weighs 16.5 pounds (including storage box).

A-4.10.5.2 Black and Decker 1330. With an 1100-watt capacity, this 5/8-inch drill has a speed of 450 rpms and weighs 15.75 pounds.

A-4.10.5.3 Black and Decker 1190-09. At 450 watts, this 3/8-inch drill has a drill speed of 2,000 rpms and weighs 5.63 pounds.

A-4.10.5.4 Sioux L1610. This 1/4-inch pneumatic drill has a reversible 1600-rpm motor.

A-4.10.5.5 Sioux 1454. At 2600 rpms, this 3/8-inch drill has an air consumption of 15 cfm at 90 psi. It weighs 2.25 pounds.

A-4.10.5.6 Sioux P1310. This 1/4-inch pneumatic drill has a speed of 2500 rpms.

A-4.10.5.7 Ingersoll-Rand 2XLA2. At 400 rpms this 1.9-horsepower pneumatic drill weighs 13.75 pounds. Its maximum speed is 500 rpms.

A-4.10.5.8 Ingersoll-Rand 3SKA. This 3.6-horsepower, pneumatic drill weighs 23 pounds and develops maximum power at 225 rpms; maximum speed is 300 rpms.

A-4.10.5.9 Ingersoll-Rand OA2N. With 0.70 horsepower at 335 rpms, this 3/8-inch pneumatic drill weighs 3.81 pounds; free speed is 550 rpms.

A-4.10.5.10 Ingersoll-Rand OOA2J. This .34-horsepower, 1/4-inch drill is air powered and weighs 2 pounds. Drill speed is 2250 rpms (free speed is 4500 rpms).

A-4.10.5.11 Chicago Pneumatic P-9288-9. This pneumatic, 3/8-inch drill weighs 3.38 pounds and has a free speed of 900 rpms.

A-4.10.5.12 Chicago Pneumatic CP-3217-PUSTU. This pneumatic, 1/2-inch drill weighs 3.5 pounds. Free speed is 500 rpms.

A-4.10.5.13 Chicago Pneumatic CP-3010-PUSTY. This pneumatic, 3/8-inch drill weighs 4.13 pounds and has a free speed of 1100 rpms.

A-4.10.5.14 Chicago Pneumatic CP0310 PASAN. This pneumatic, 1/2-inch drill weighs 8.25 pounds; free speed is 925 rpms.

A-4.10.6 Power chisels

All power chisels surveyed were pneumatically powered.

A-4.10.6.1 Chicago Pneumatic CP-4444-RUSAB. This power chisel weighs 2.31 pounds and delivers 2160 blows per minute.

A-4.10.6.2 Chicago Pneumatic CP-444-RUTAB. This power chisel weighs 2.75 pounds and delivers 1740 blows per minute.

A-4.10.6.3 Chicago Pneumatic CP-444-RURAB. This power chisel weighs 2.25 pounds and delivers 2580 blows per minute.

A-4.10.6.4 Chicago Pneumatic CP-446-RUTAB. This power chisel weighs 3.5 pounds and delivers 1500 blows per minute.

A-4.10.6.5 Chicago Pneumatic CP-447-RUSAB. This power chisel weighs 4.75 pounds and delivers 1560 blows per minute.

A-4.10.6.6 Chicago Pneumatic CP-4447-RUTAB. This power chisel weighs 5.13 pounds and delivers 1140 blows per minute.

A-4.10.6.7 Chicago Pneumatic CP-447-RUVAB. This power chisel weighs 6 pounds and delivers 900 blows per minute.

A-4.10.6.8 Sioux Air Slugger 722. This power chisel weighs 3.25 pounds and delivers 3500 blows per minute. Air consumption is CSM at 90 psi; stroke is 2 inches.

A-4.10.6.9 Sioux Air Slugger 720. This power chisel weighs 4.75 pounds and delivers 2000 blows per minute. Air consumption is 4 CSM at 90 psi; stroke is 3 inches.

A-4.10.6.10 Black and Decker 5161. This power chisel weighs 3.4 pounds and delivers 4000 strokes per minute.

A-4.10.6.11 Black and Decker 5162. This power chisel weighs 4 pounds and delivers 3000 blows per minute.

A-4.10.6.12 Black and Decker 5164. This power chisel weighs 4 pounds and delivers 3000 blows per minute.

A-4.10.7 Power Hammers

A-4.10.7.1 Black and Decker 5026. This 63-pound (with cord) power hammer uses a standard 120V, 15 amp receptacle or 2500-watt generator. At 610 blows per minute it delivers 60 foot-pound blows. The 1 1/8-inch by 6-inch hex shank uses existing airbreaker accessories. Maximum power output is 2050 watts.

A-4.10.7.2 Black and Decker 5025. The hole drilling capacity of this power hammer is 11/16 inches to 2 1/2 inches. It uses 120V, 11 amps, and its speed at rated load is 1800 rpms. It weighs 31.25 pounds.

A-4.10.7.3 Black and Decker 5041-09. The length of this power hammer is 15.75 inches; its weight is 10 pounds. Under load, its speed is 600 rpms. At 120V, 4.8 amps, it requires 550 watts.

A-4.10.7.4 Black and Decker 5042-09. With a length of 15.75 inches, this power hammer weighs 13 pounds. Under load, its speed is 550 rpms. Rated at 120V, 6 amps, it requires 700 watts.

A-4.10.7.5 Black and Decker 5043-09. This power hammer is rated at 120V, 6.6 amps, and requires 750 watts. Under load, its speed is 300 rpms. With a length of 15.75 inches, it weighs 13.5 pounds.

A-4.10.7.6 Black and Decker 5079-09. The lightest of the Black and Decker power hammers, the 5079-09 weighs 6 pounds (with cord), is 11.5 inches long, and is rated at 120 V, 4.5 amps. No load speed is 3400 rpms, and it requires 420 watts.

A-4.10.7.7 Chicago Pneumatic CP-0456-LESAR. With a weight of 3.5 pounds, and a length of 8.63 inches, this power hammer delivers 4300 blows per minute. It is equipped with a straight handle and self-closing lever throttle.

A-4.10.7.8 Chicago Pneumatic CP-0456-BESAR. Equipped with a straight handle and self-closing lever throttle, this power hammer weighs 4 pounds and delivers 4300 blows per minute. Its length is 9.88 inches.

A-4.10.7.9 Chicago Pneumatic CP-0457-LASAR. This power hammer weighs 2.75 pounds, delivers 5160 blows per minute, is equipped with a straight handle and self-closing lever throttle, and has a length of 7.5 inches.

A-4.10.7.10 Chicago Pneumatic CP-0458-PASAR. Equipped with a pistol-grip handle and self-closing outside trigger throttle, this 5.75-pound power hammer delivers 4100 blows per minute. Its length is 7.5 inches.

A-4.10.7.11 Chicago Pneumatic CP-9356. This power hammer weighs 3.75 pounds, delivers 4100 blows per minute, and is equipped with a straight handle and self-closing lever throttle. Its length is 9.38 inches.

A-4.10.7.12 Chicago Pneumatic CP-9356-PH. Equipped with a straight handle and push throttle, this power hammer weighs 4 pounds and delivers 4600 blows per minute. Its length is 12.13 inches.

A-4.10.8 Power Shears

A-4.10.8.1 Sierra Extraction Tool I, II, and III. These shears use air-activated hydraulic power (no need for heavy power unit) and their 4-inch cutter jaws exert 16,800 psi of pressure. They weigh 22 pounds each.

A-4.10.8.2 HRT Shear P/N 36000. With a working pressure of 10,500 psi the maximum cutting capacity of these power shears is 4.5 inches. A double-acting cylinder opens and closes blades hydraulically. This tool weighs 32 pounds (with hose).

A-4.10.8.3 HK Porter 1790 CDX. This model comprises a hand pump, hose, and power cutter. It weighs 18.5 pounds. Maximum cutting capacity is 3 inches; cutting power is 25,000 psi.

A-4.10.8.4 Enerpac Cable Cutter WCS 100. These power shears cut standard copper or aluminum cable through 1,000,000 circular mils. With a cutting force of 13,200 psi, the cutting capacity is 4 inches. These shears weigh 25 pounds.

A-4.10.8.5 Hurst 0-90. These shears weigh 33 pounds. Maximum cutting capacity is 4 inches; cutting power is 30,000 psi.

A-4.10.8.6 Hurst 0-150. With 25,000 psi of cutting power, these shears weigh 36 pounds and have a maximum cutting capacity of 6.5 inches.

SECTION A-5

DISCUSSION

Selection of the best tool or tools is crucial to the success of a rescue operation. Although conditions at the scene may vary, rescue personnel first to arrive must have equipment which fulfills operational requirements. In some cases, direct ground access may be possible; in others, a portable ladder may be required to climb to an elevated position. Supplementary lighting may be needed at night. However, time for assessment of conditions and tool selection is minimal.

Safety is paramount in all phases of rescue operations. In aircraft rescue where flammable fluids and vapors are present, flammability features of the tools must be considered. The information in this study defines various tool parameters important in assessing and comparing tool capabilities. Data on flammability features are not readily available; however, some suppliers provide this information upon request.

SECTION A-6
CONCLUSIONS

A large variety of tools is available for use in rescue of personnel from aircraft. As discussed, correct initial selection of tools is critical. Accordingly, the Department of the Air Force and the Air Force Engineering and Services Center have initiated a program to design and develop a single optimum rescue tool. This state-of-the-art survey was prepared to support the design action.

(The reverse of this page is blank)

APPENDIX B

COMPARATIVE BAR GRAPHS-DISPLACING TOOLS

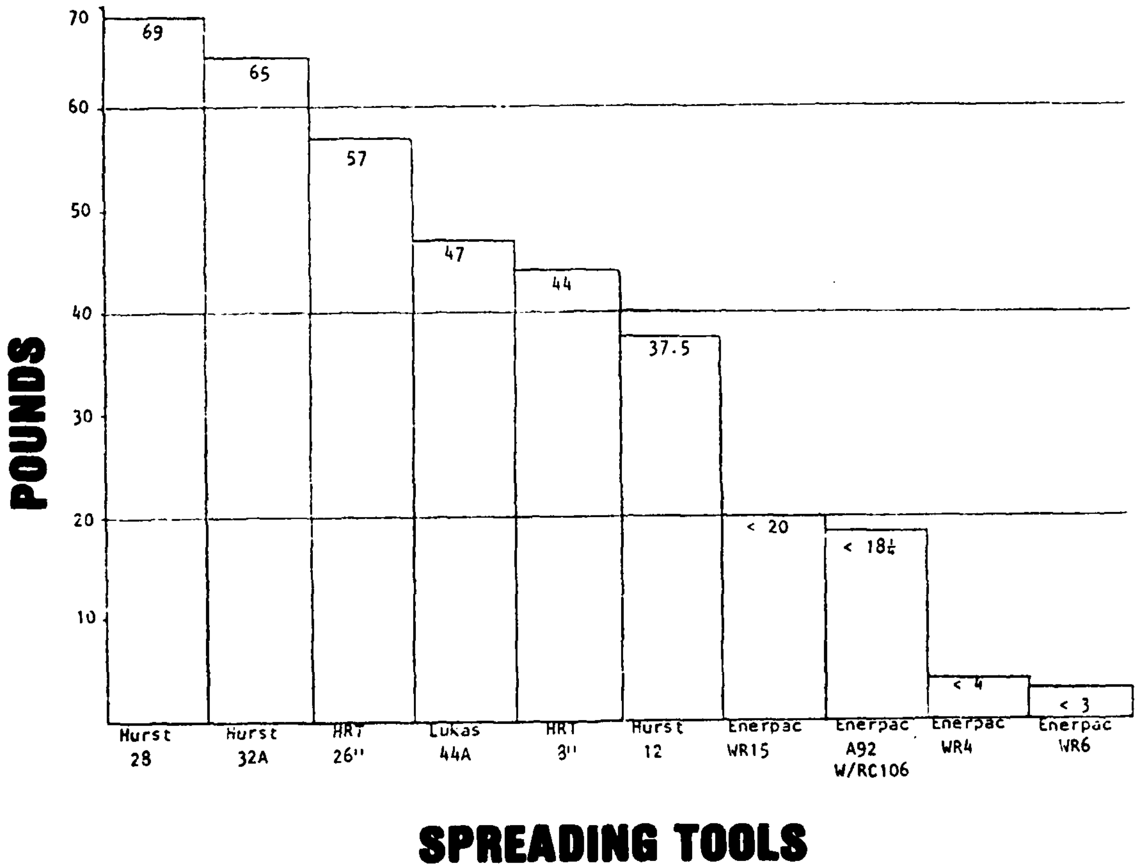


Figure B-1. Weight of Spreading Tools

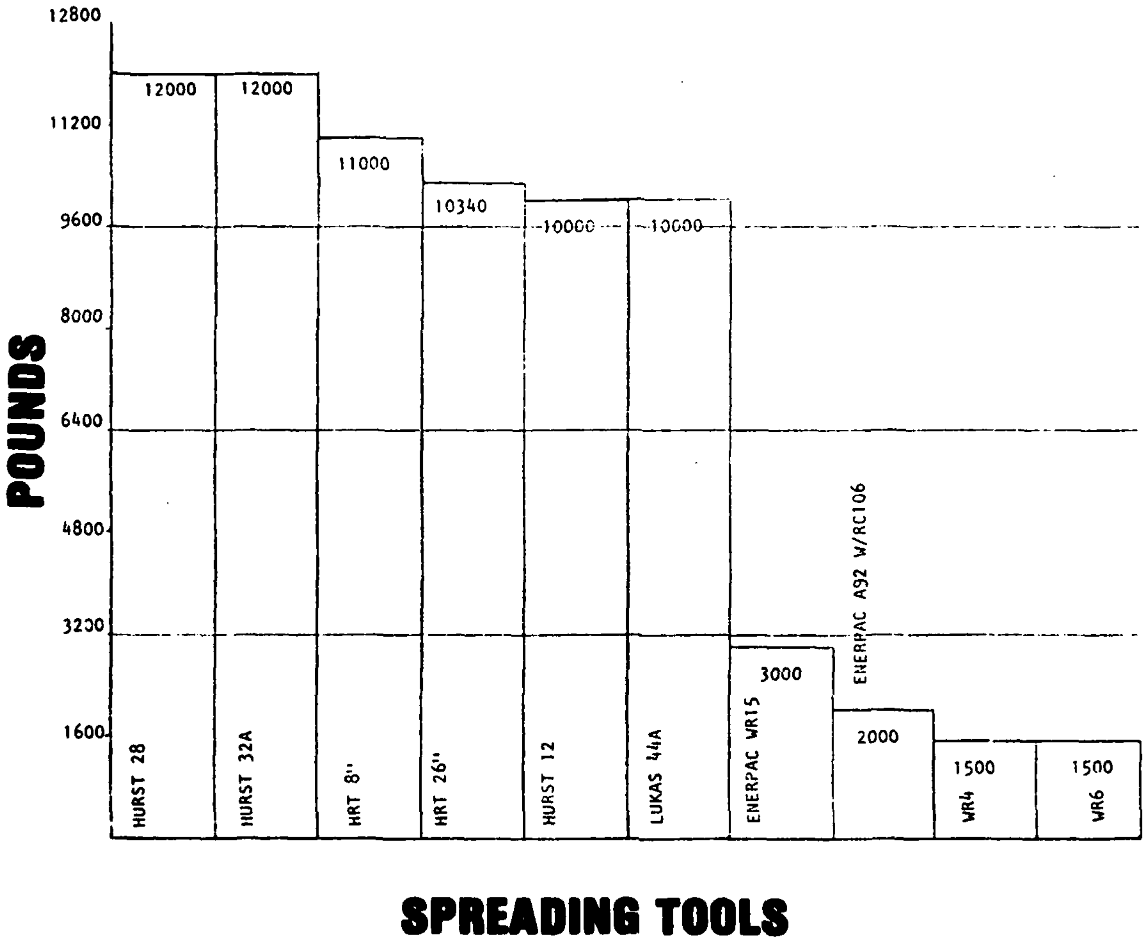


Figure B-2. Opening Forces of Spreading Tools

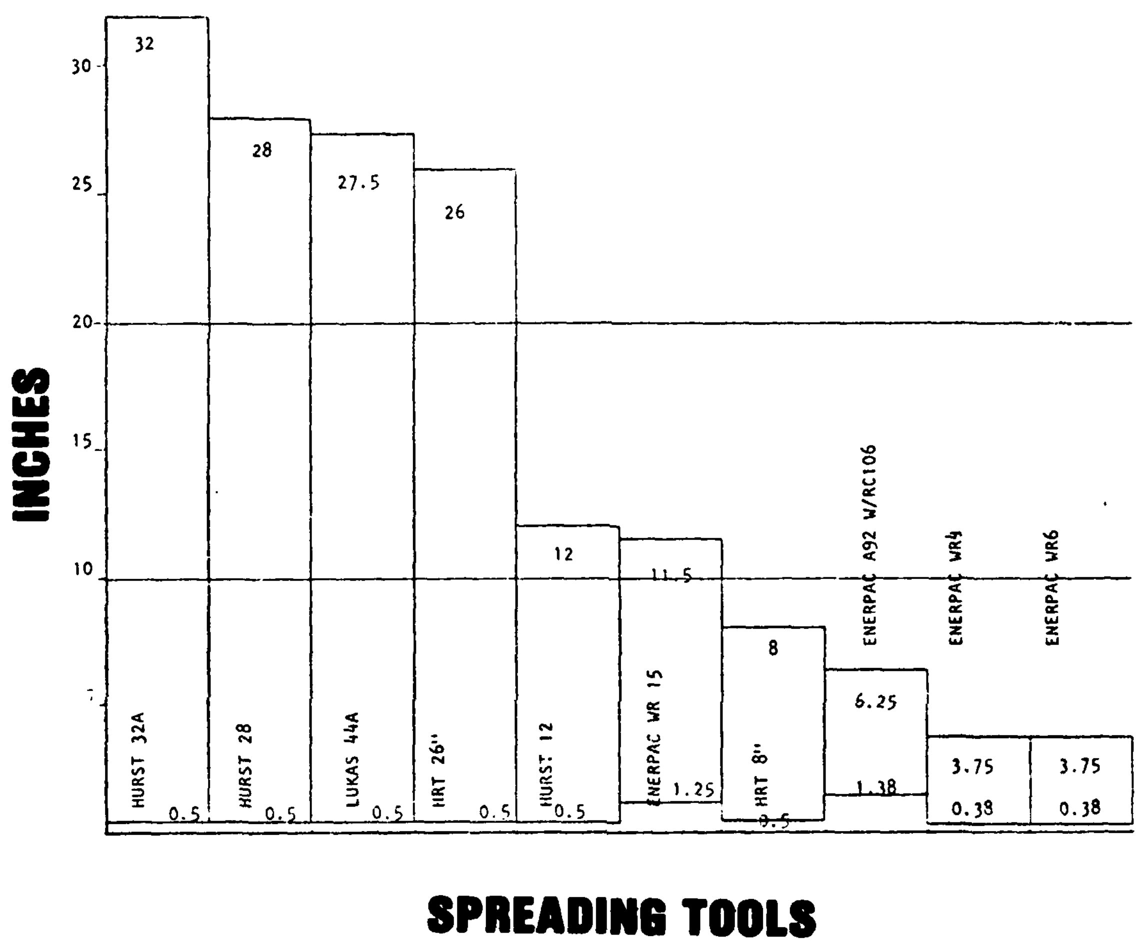


Figure B-3. Opening Spread Distance of Spreading Tools

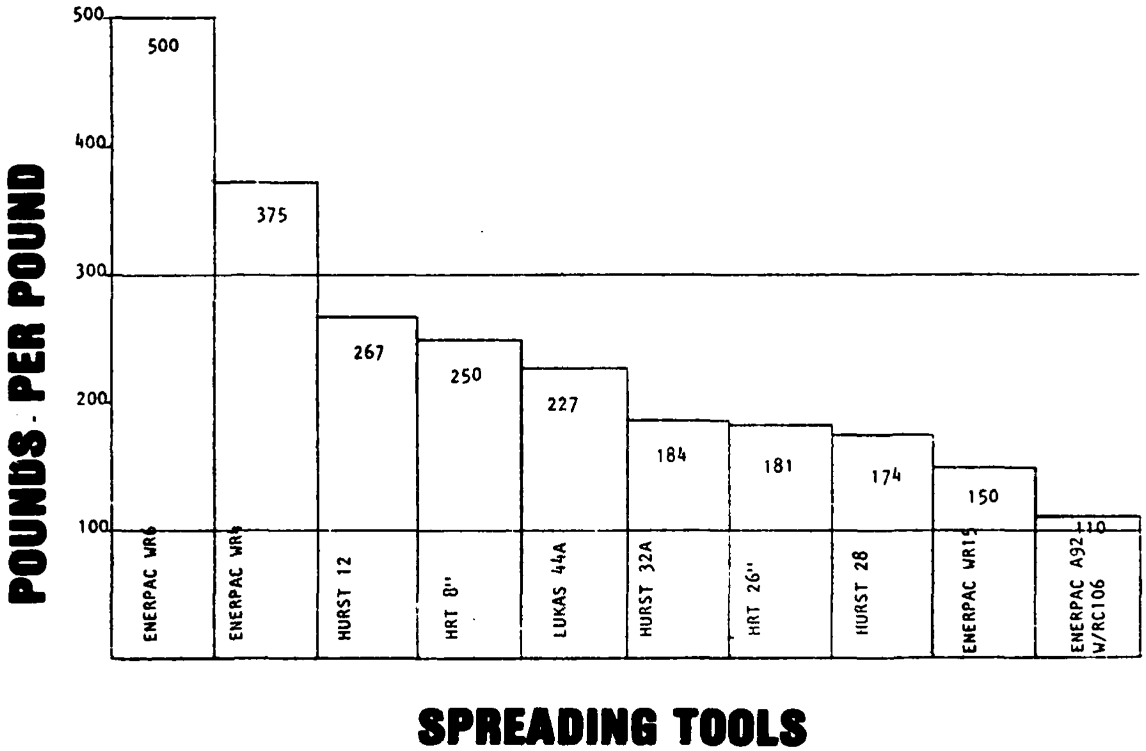


Figure B-4. Spreading Forces Per Pound of Tool Weight

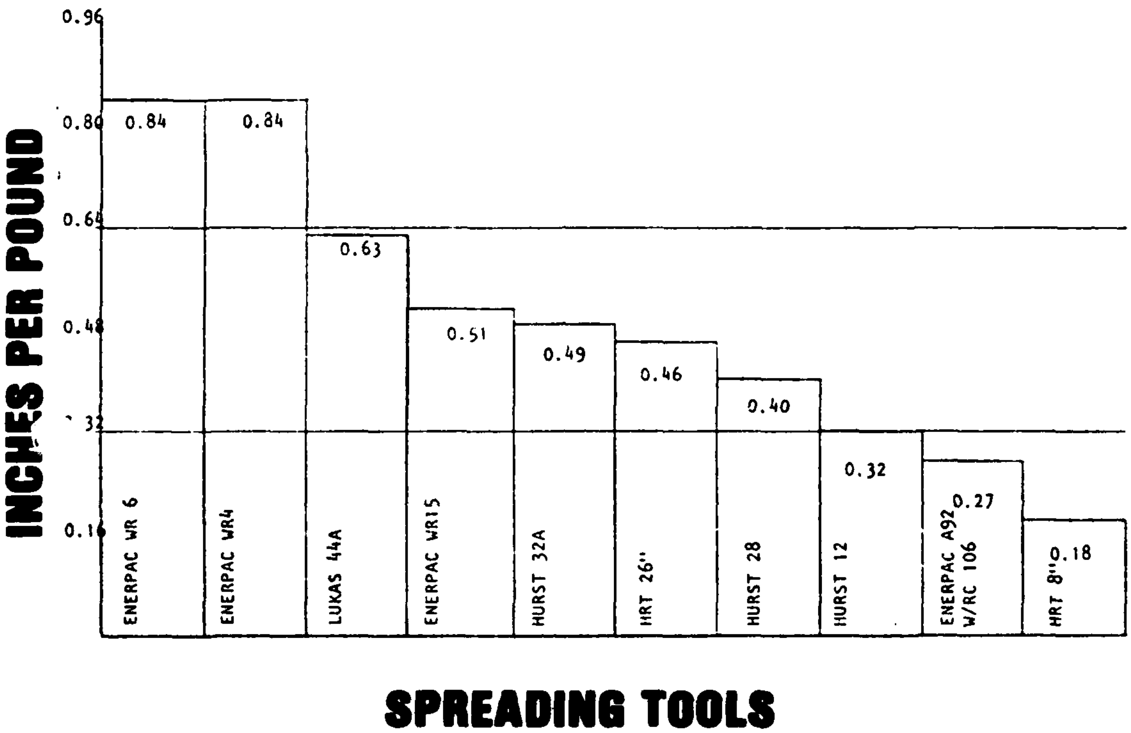


Figure B-5. Opening Capacities of Spreading Tools Per Pound of Weight

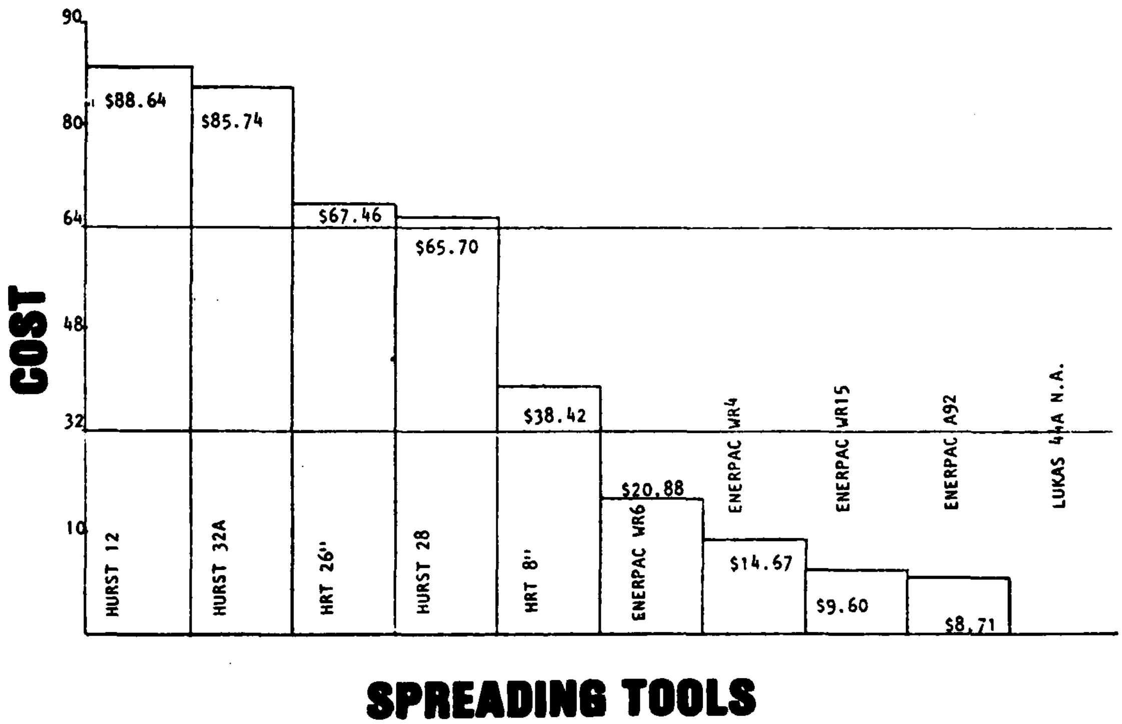


Figure B-6. Cost Per Pound of Spreading Tools

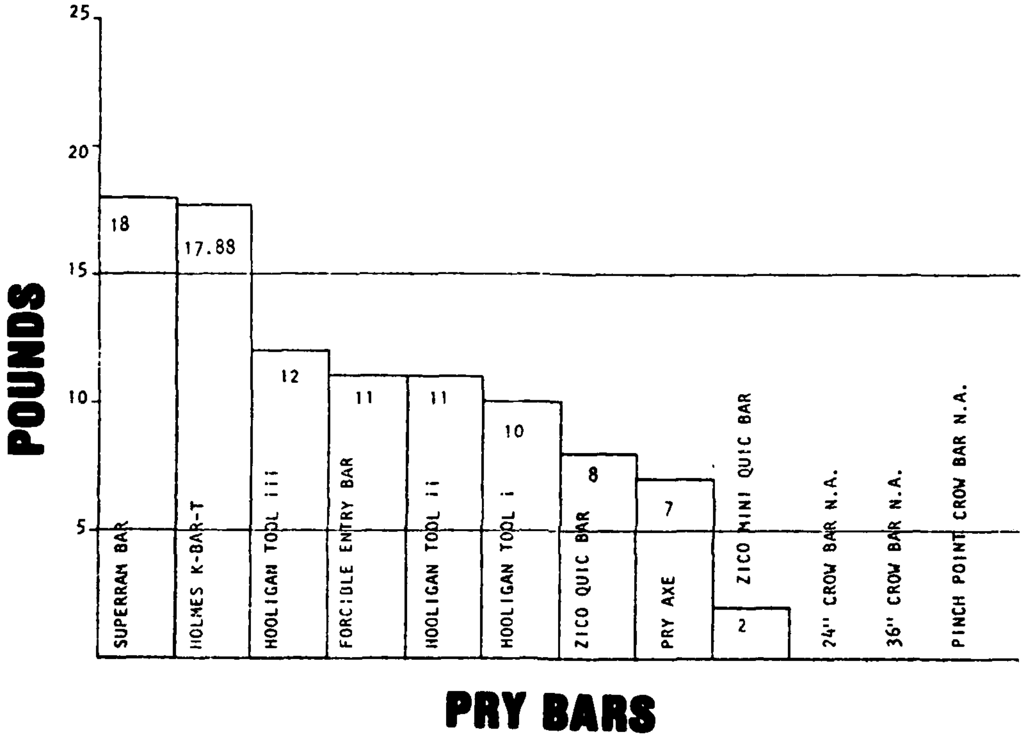


Figure B-7. Weight of Pry Bars

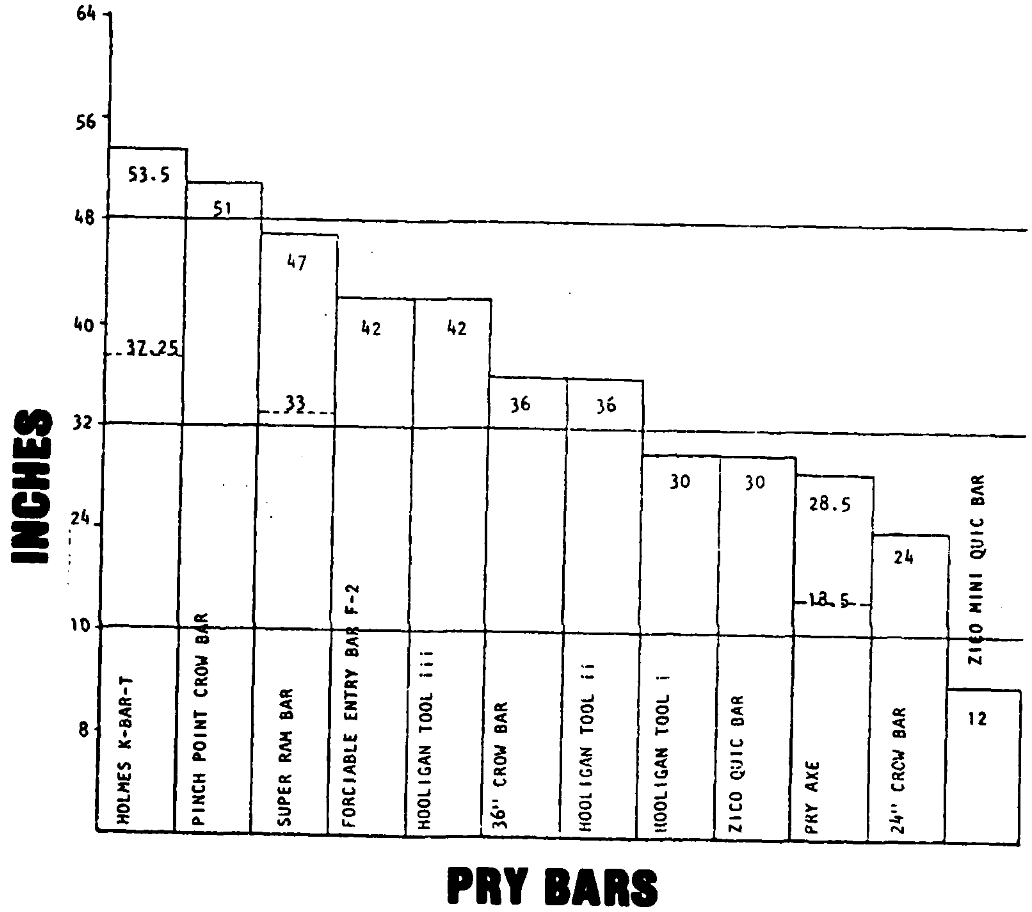


Figure B-8. Length of Pry Bars

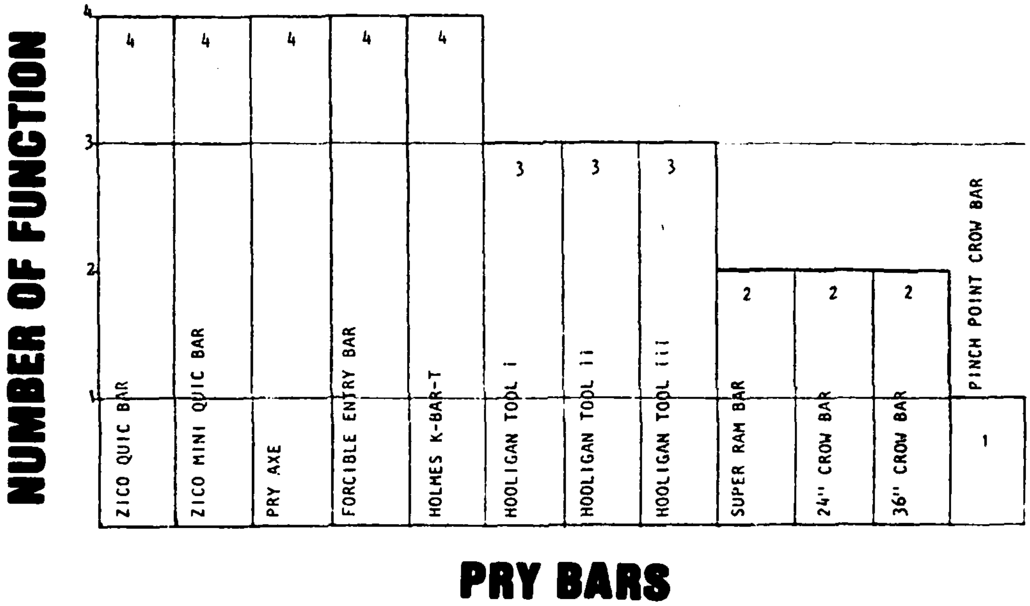


Figure B-9. Number of Functions of Pry Bars

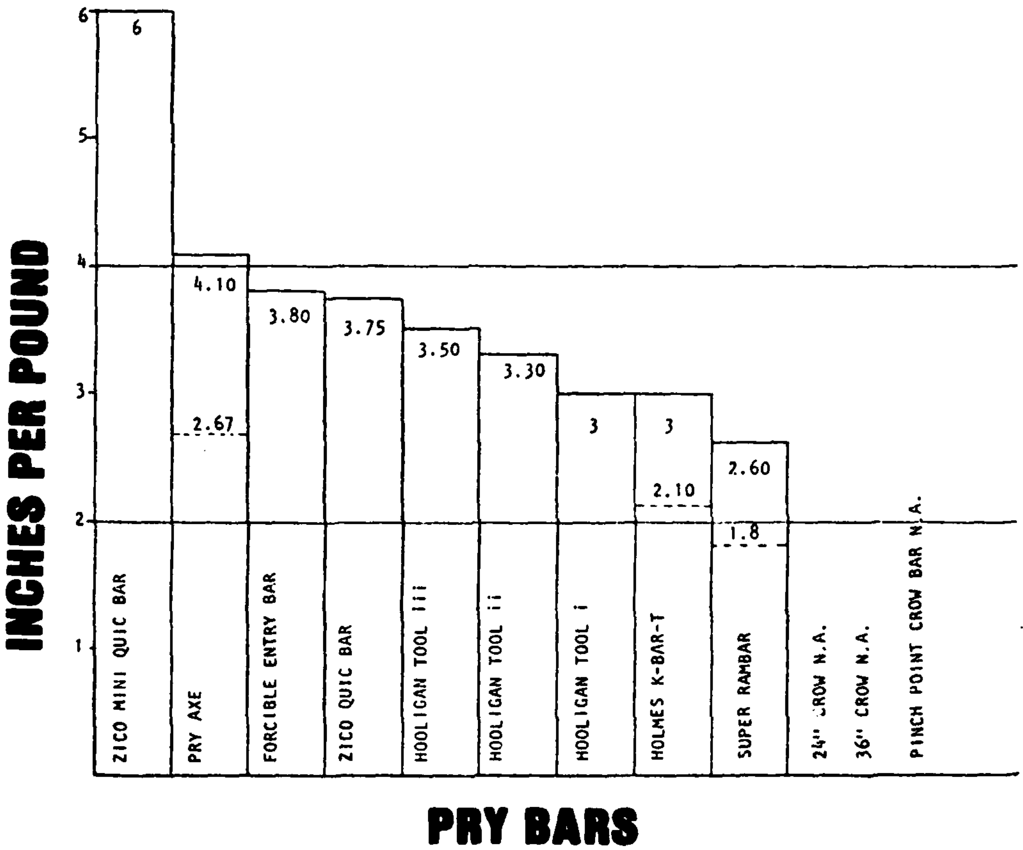


Figure B-10. Pry Bar Lengths Per Unit Weight

(The reverse of this page is blank.)

APPENDIX C

COMPARATIVE BAR GRAPHS

CUTTING TOOLS

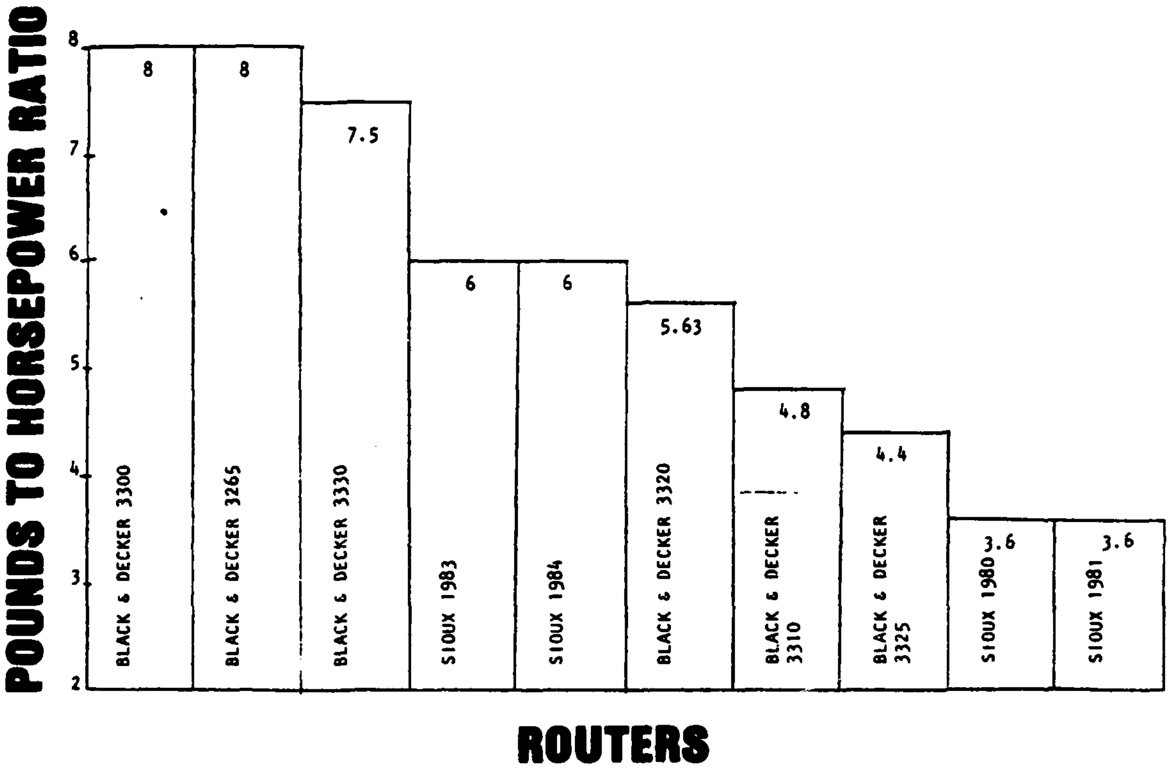


Figure C-1. Router Weight-to-Power Ratios

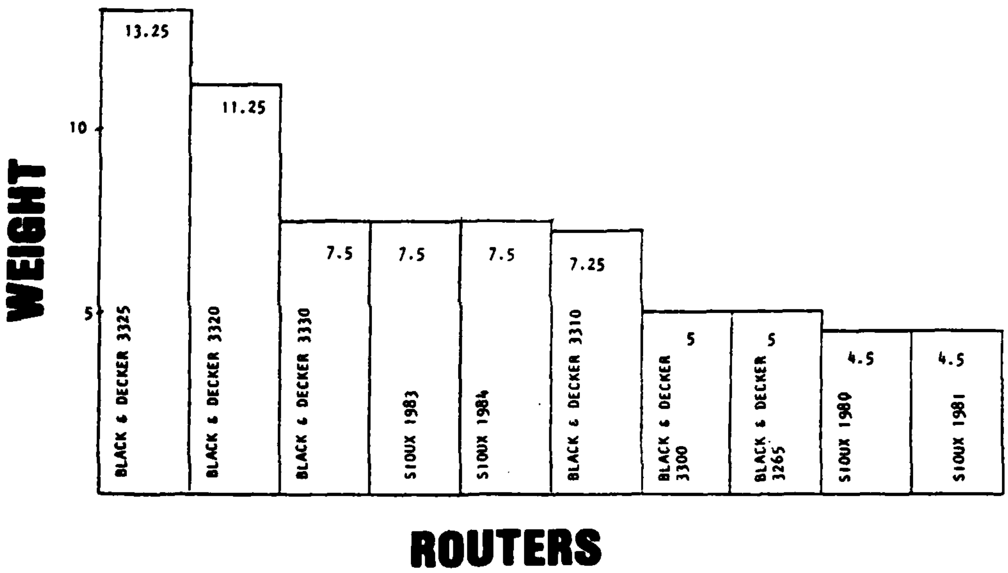


Figure C-2. Weight of Routers

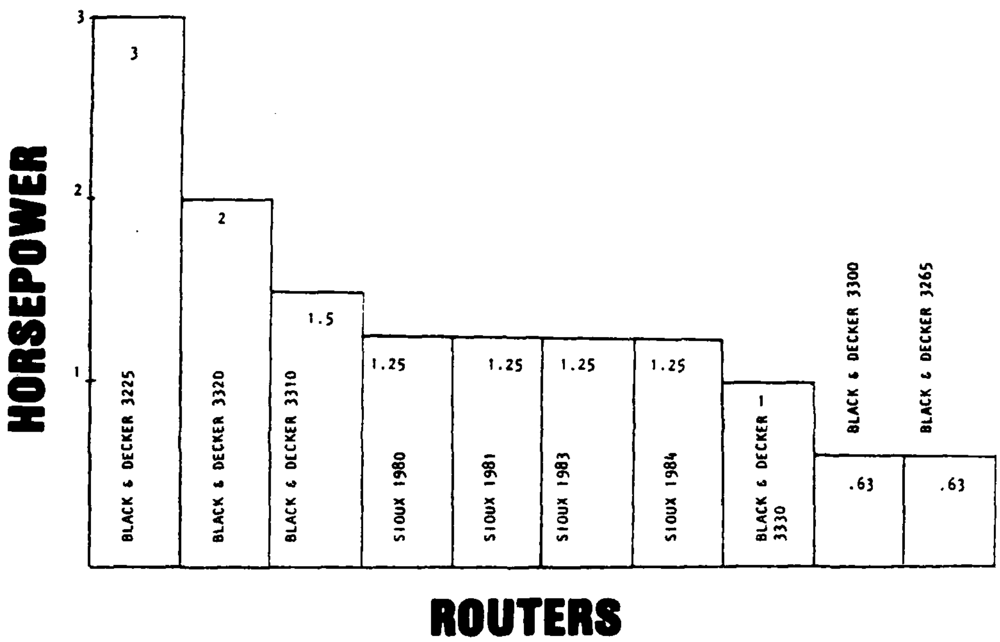


Figure C-3. Power of Routers

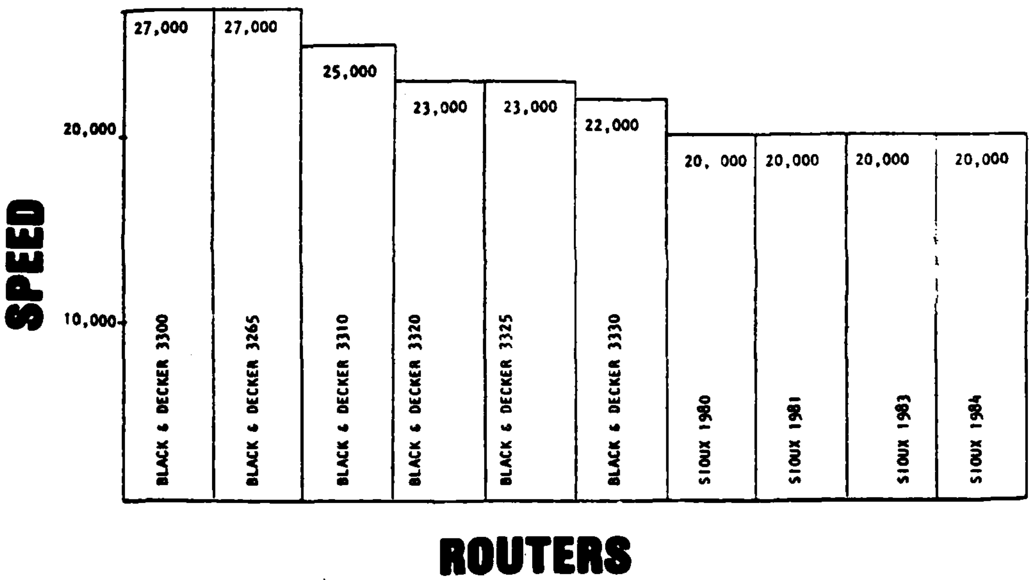


Figure C-4. Router Speed

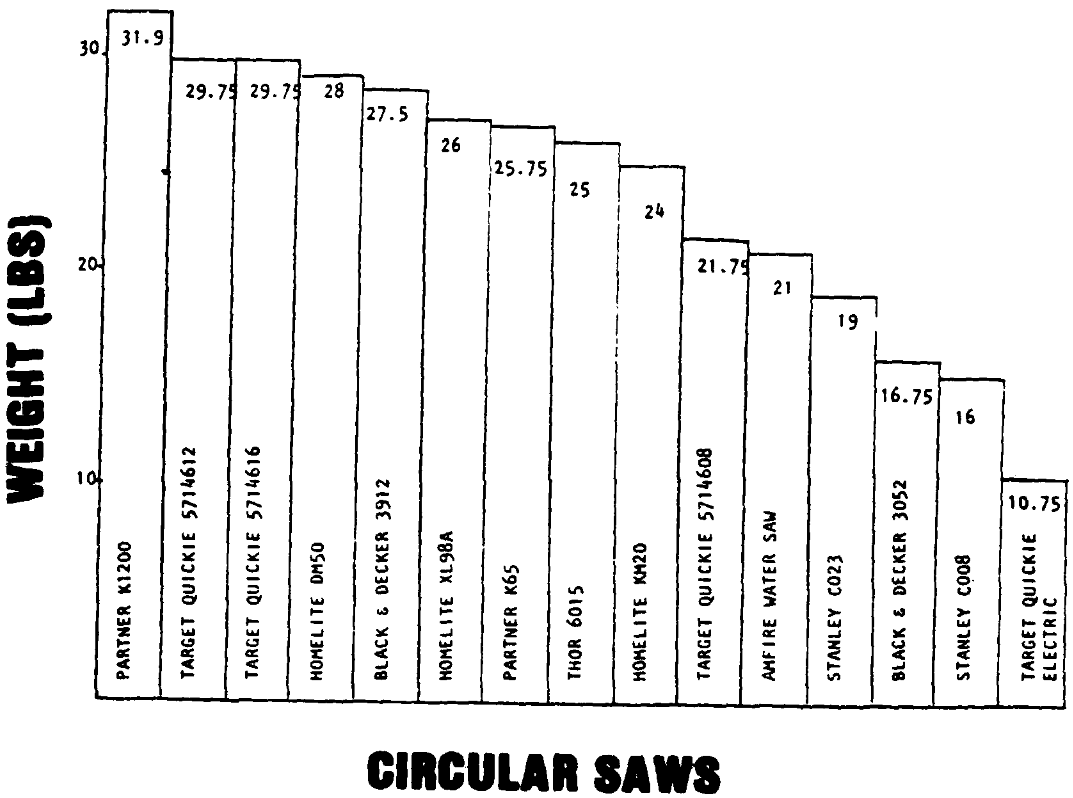


Figure C-5. Weights of Circular Saws

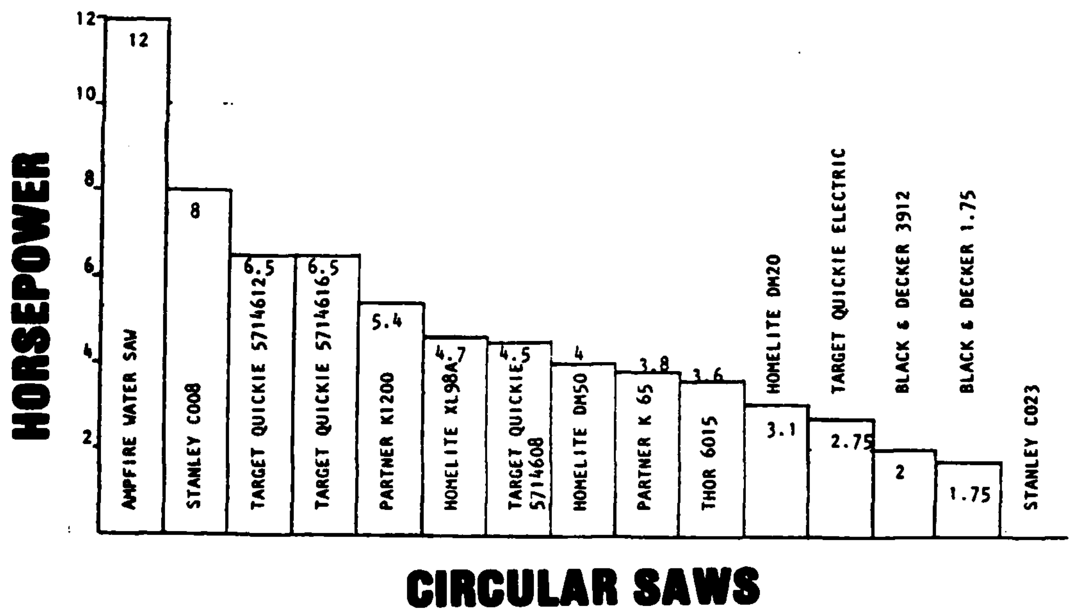


Figure C-6. Horsepower of Circular Saws

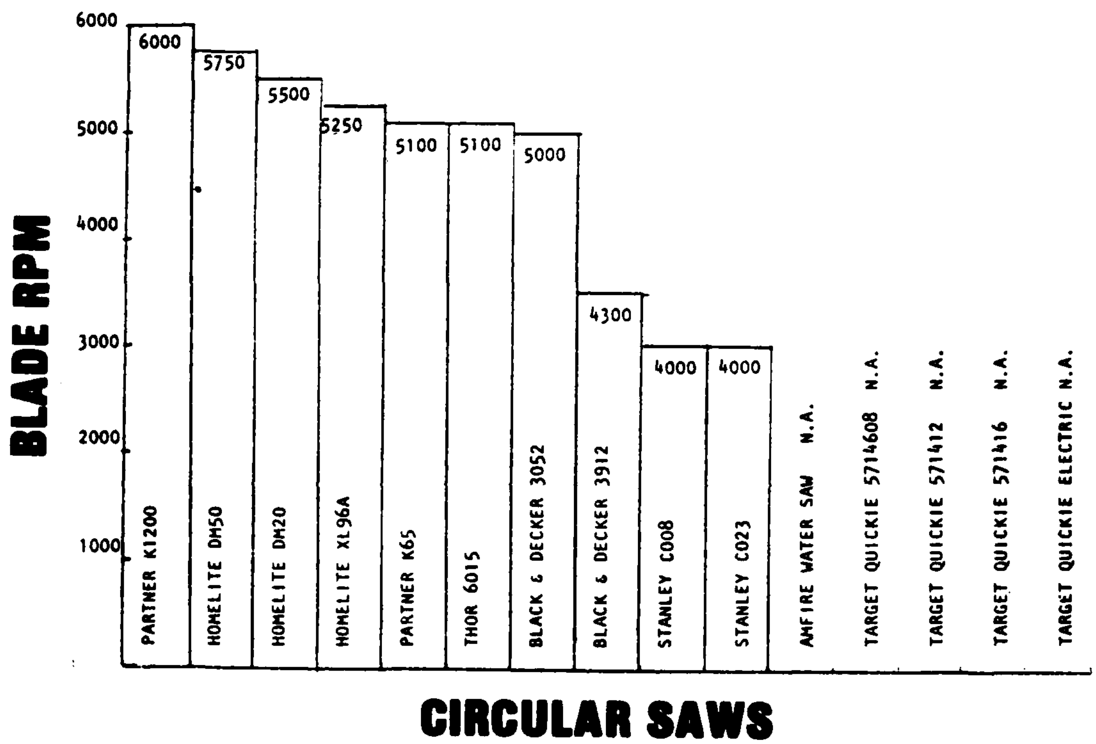


Figure C-7. RPM of Circular Saw Blades

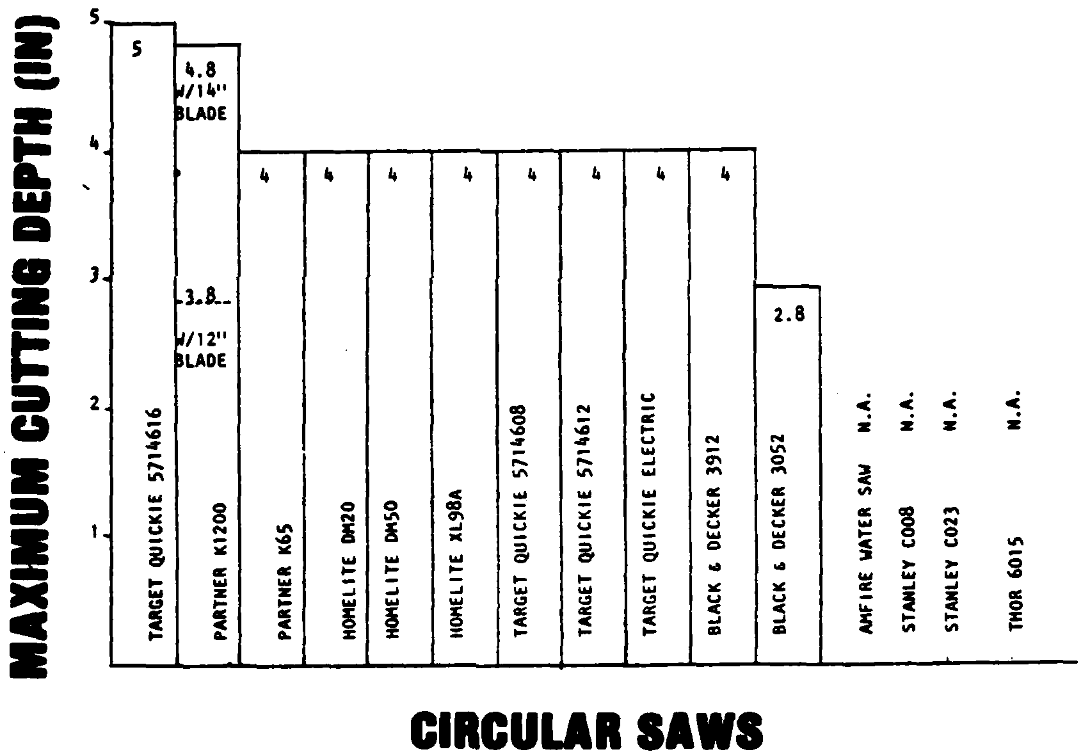


Figure C-8. Cutting Depth of Circular Saws

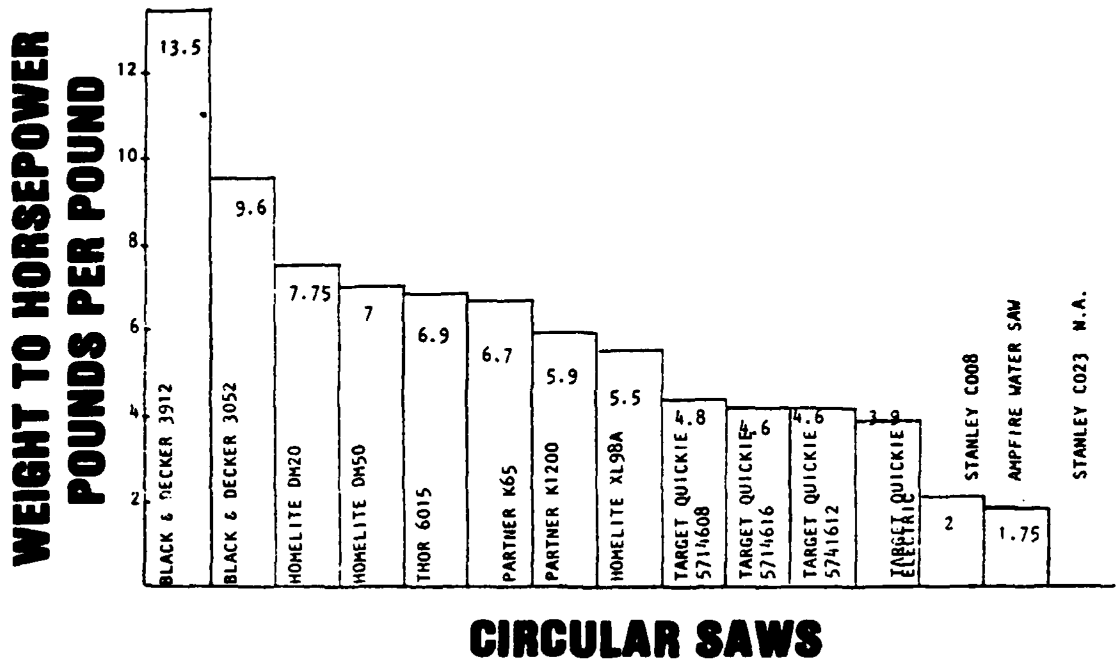


Figure C-9. Weight-to-Horsepower of Circular Saws

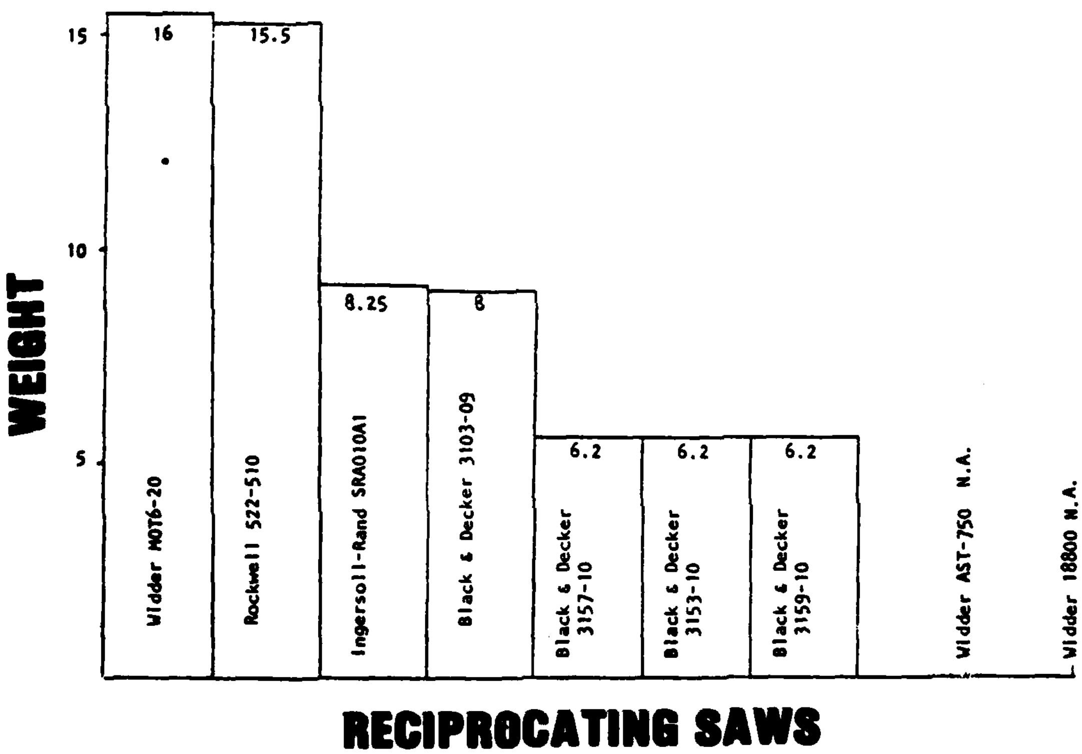


Figure C-10. Weight of Reciprocating Saws

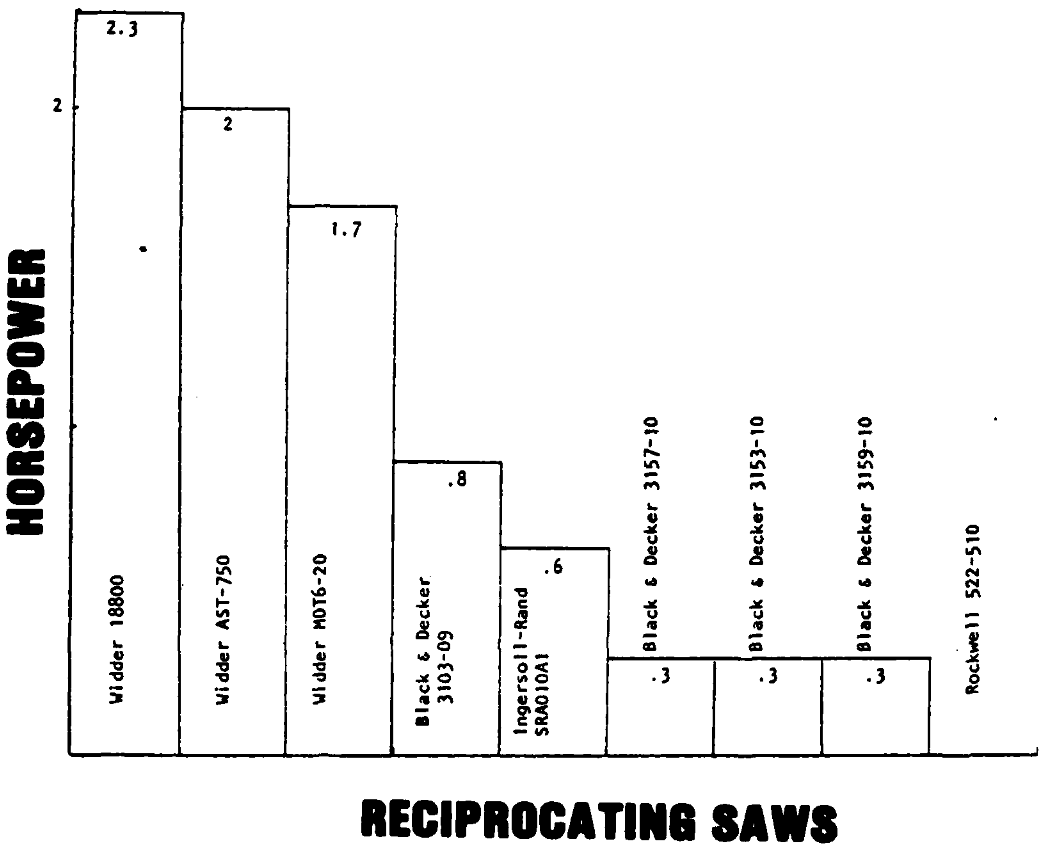


Figure C-11. Horsepower of Reciprocating Saws

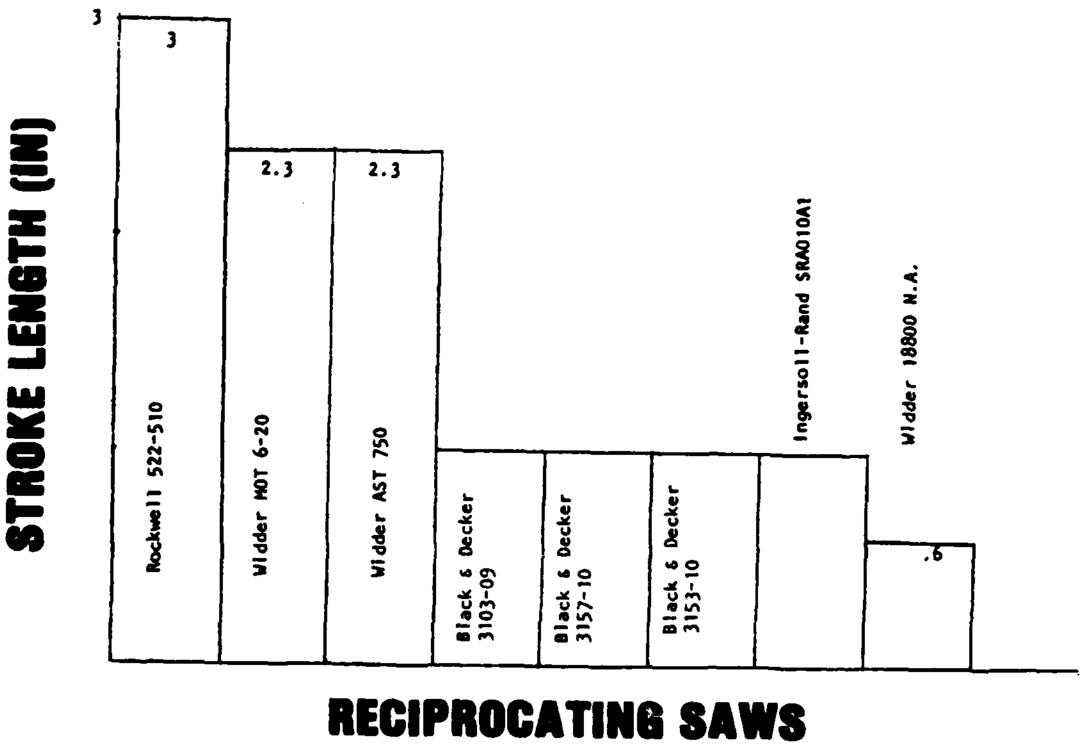


Figure C-12. Stroke Length of Reciprocating Saws

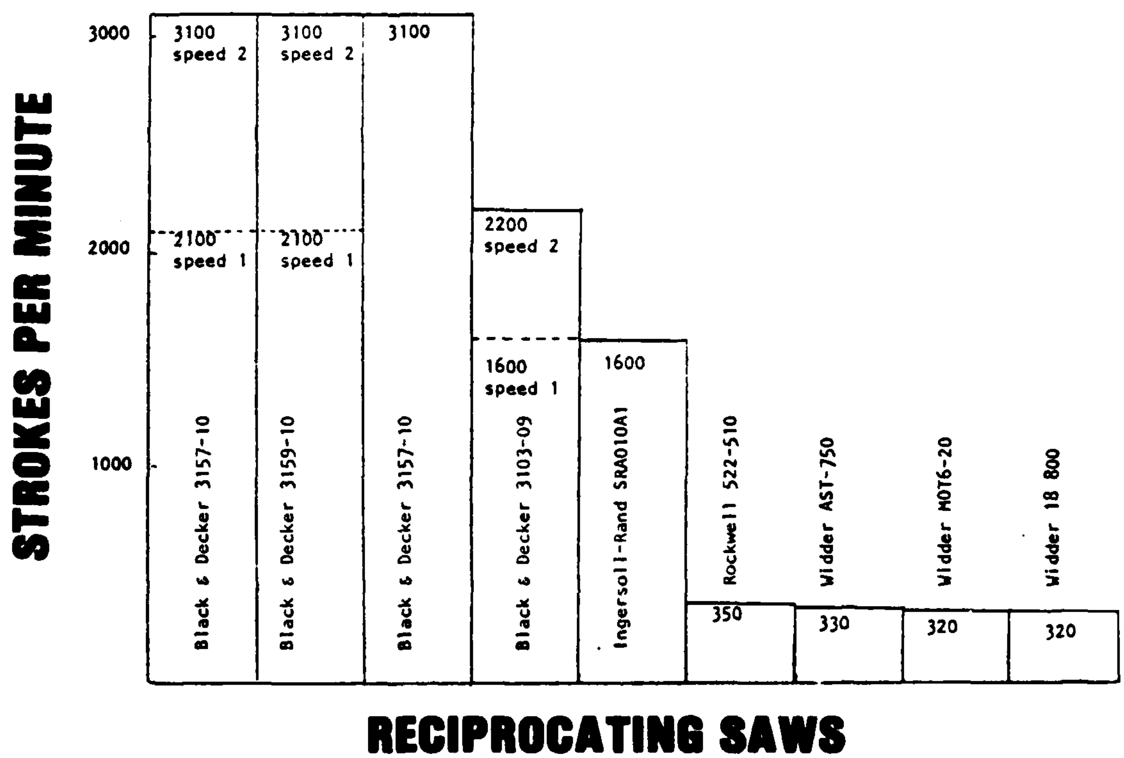


Figure C-13. Strokes Per Minute of Reciprocating Saws

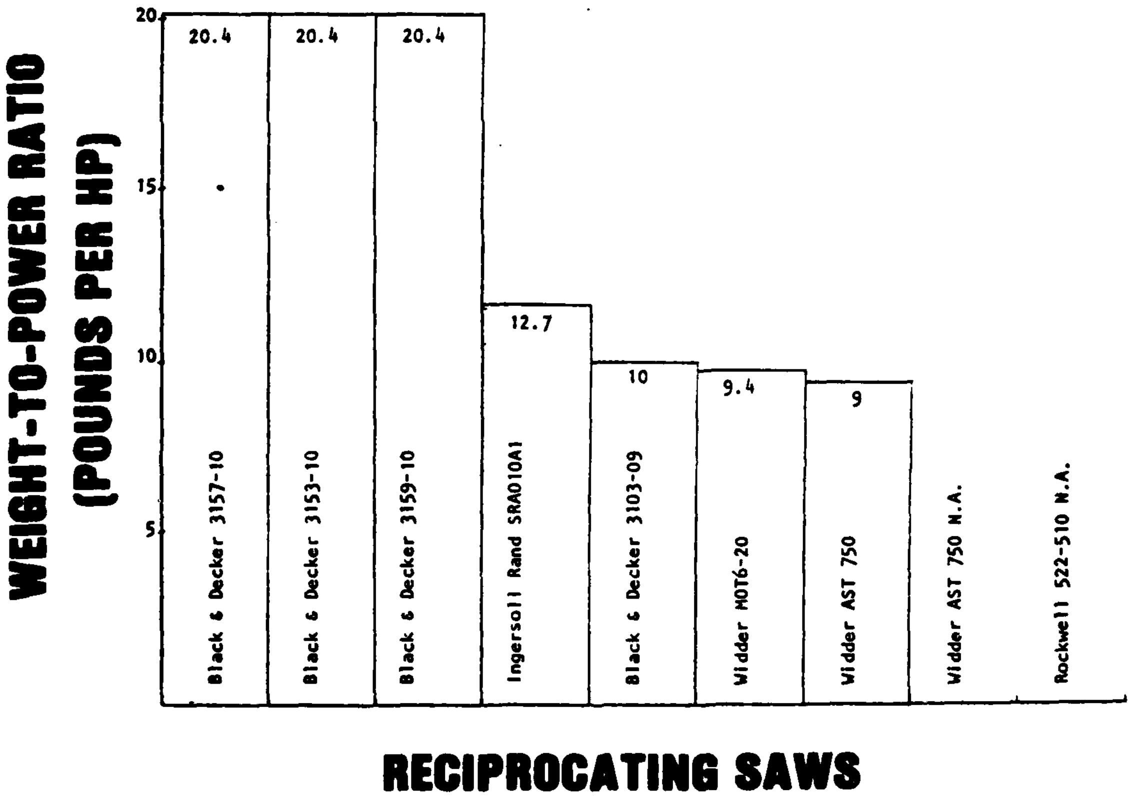


Figure C-14. Reciprocating Saws Rate-to-Horsepower Ratios

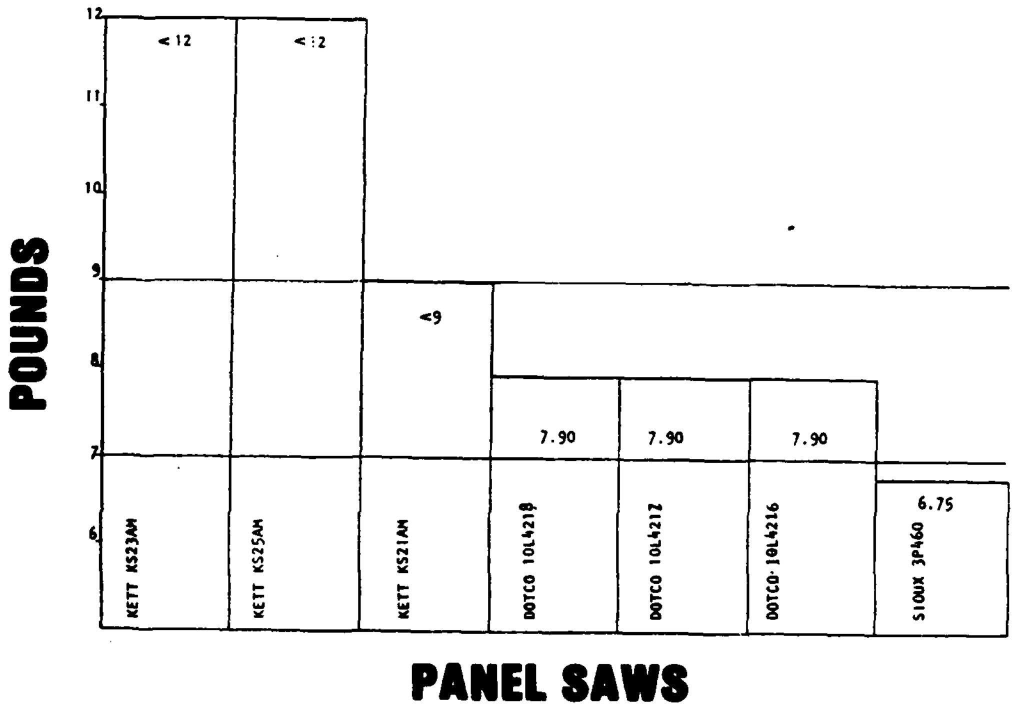


Figure C-15. Weight of Panel Saws

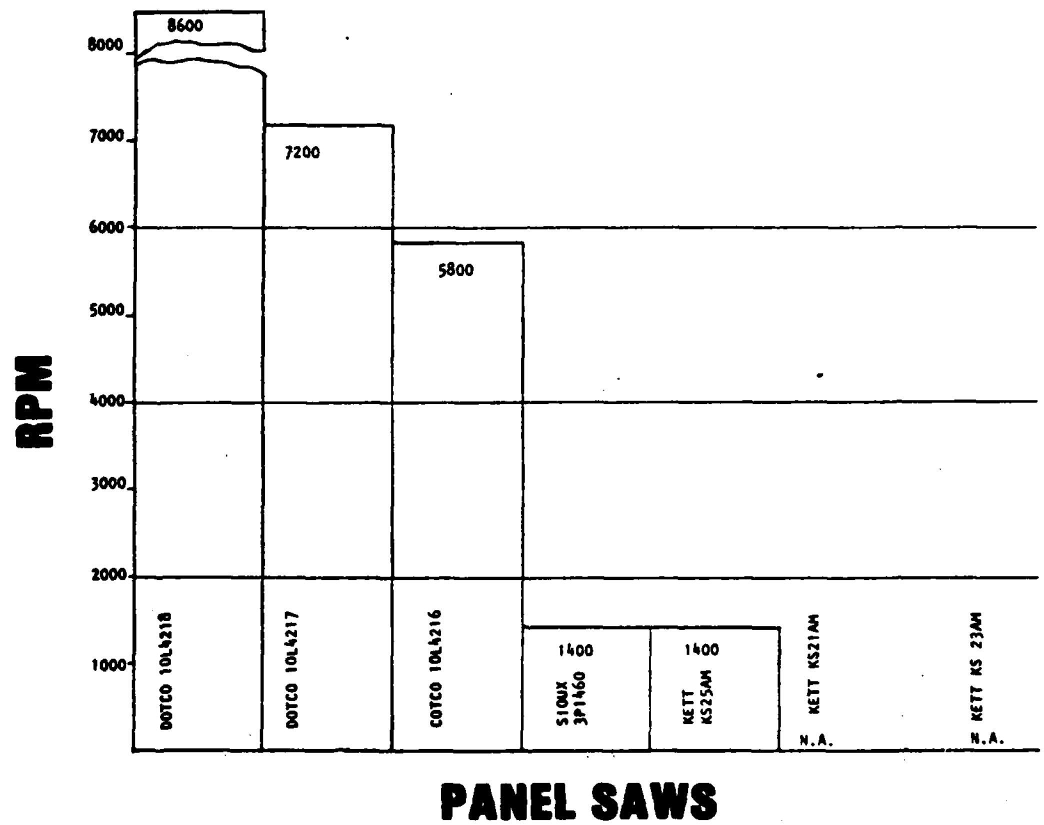


Figure C-16. Speed of Panel Saws

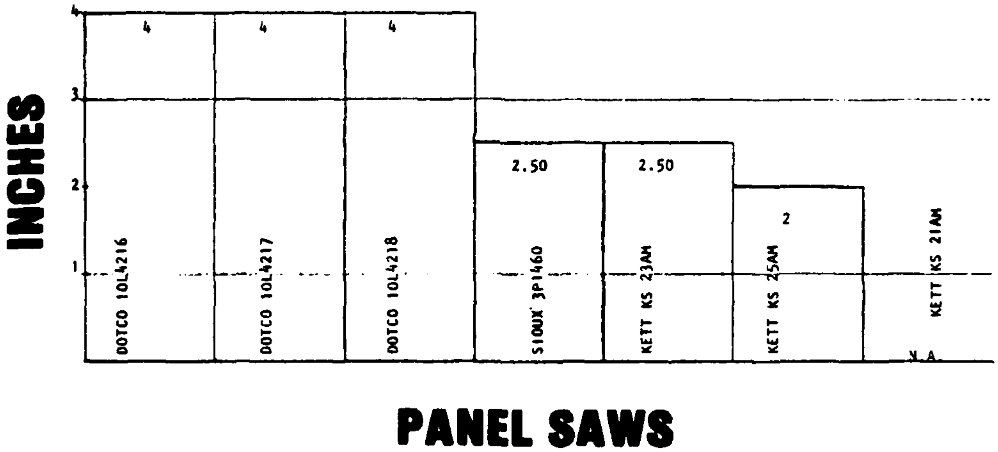


Figure C-17. Blade Diameter of Panel Saws

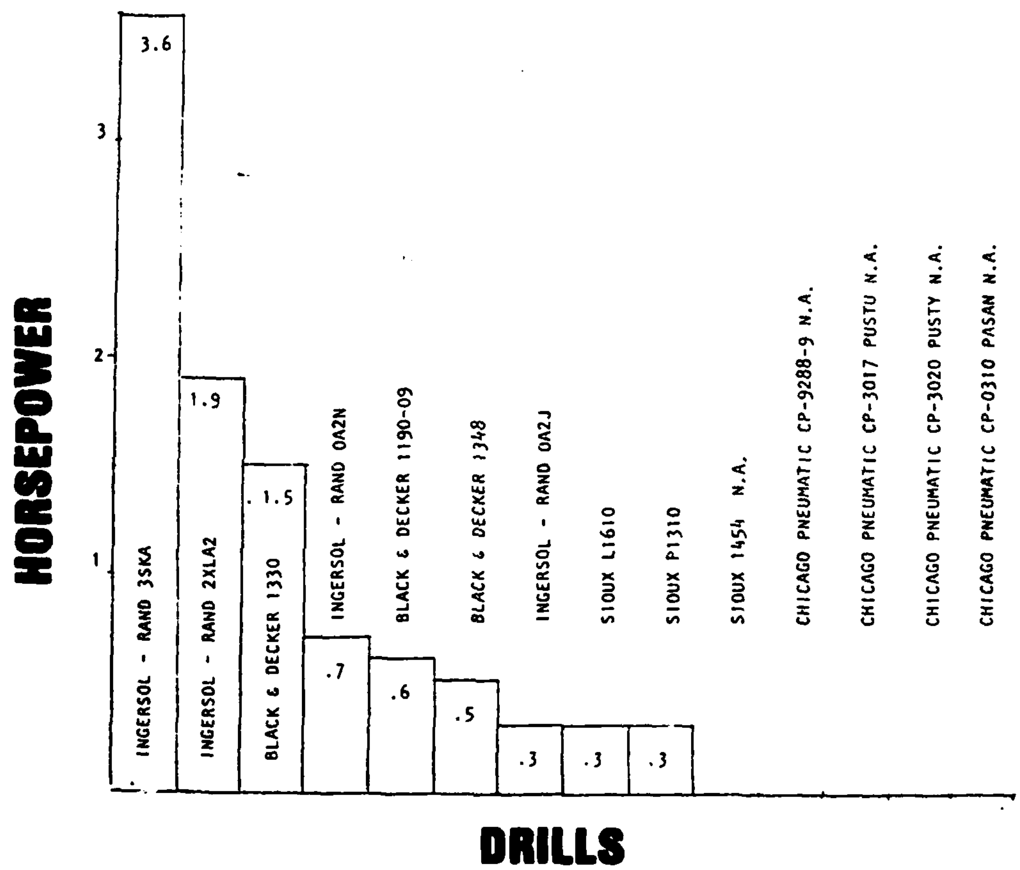


Figure C-18. Horsepower of Drills

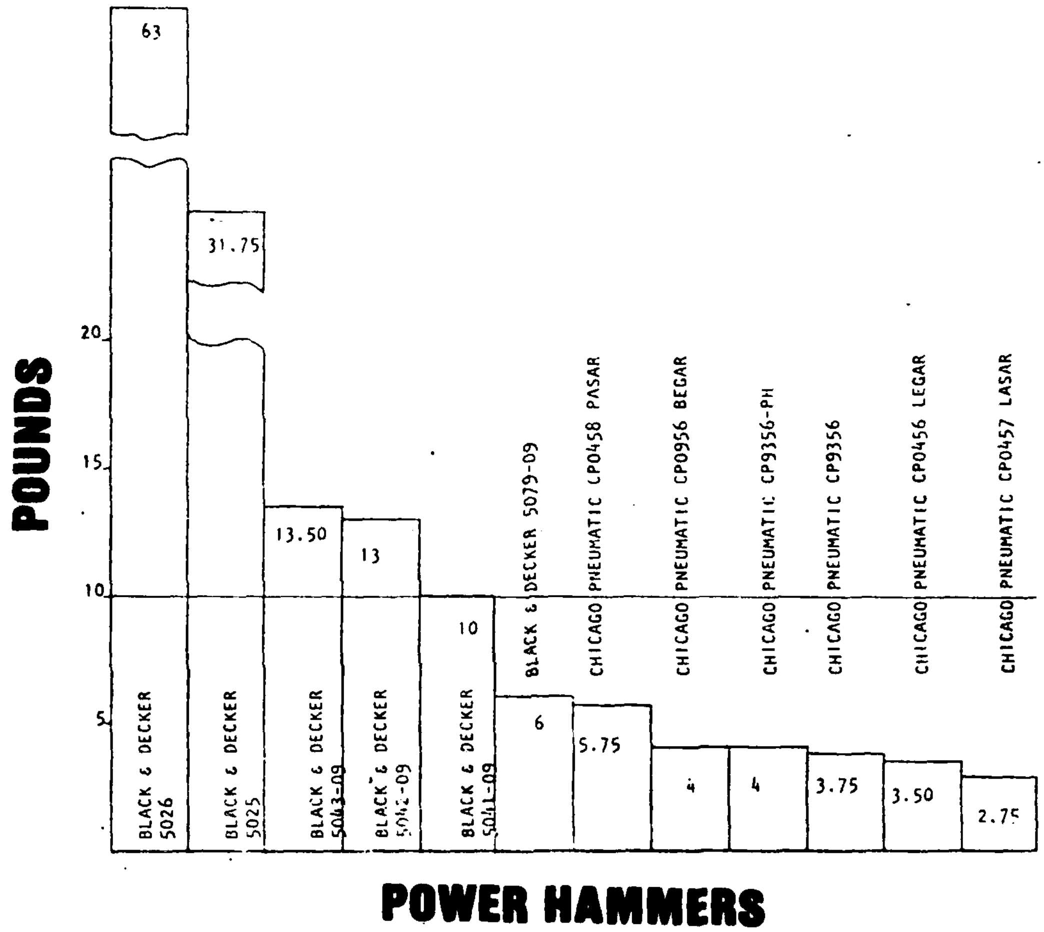


Figure C-19. Weight of Power Hammers

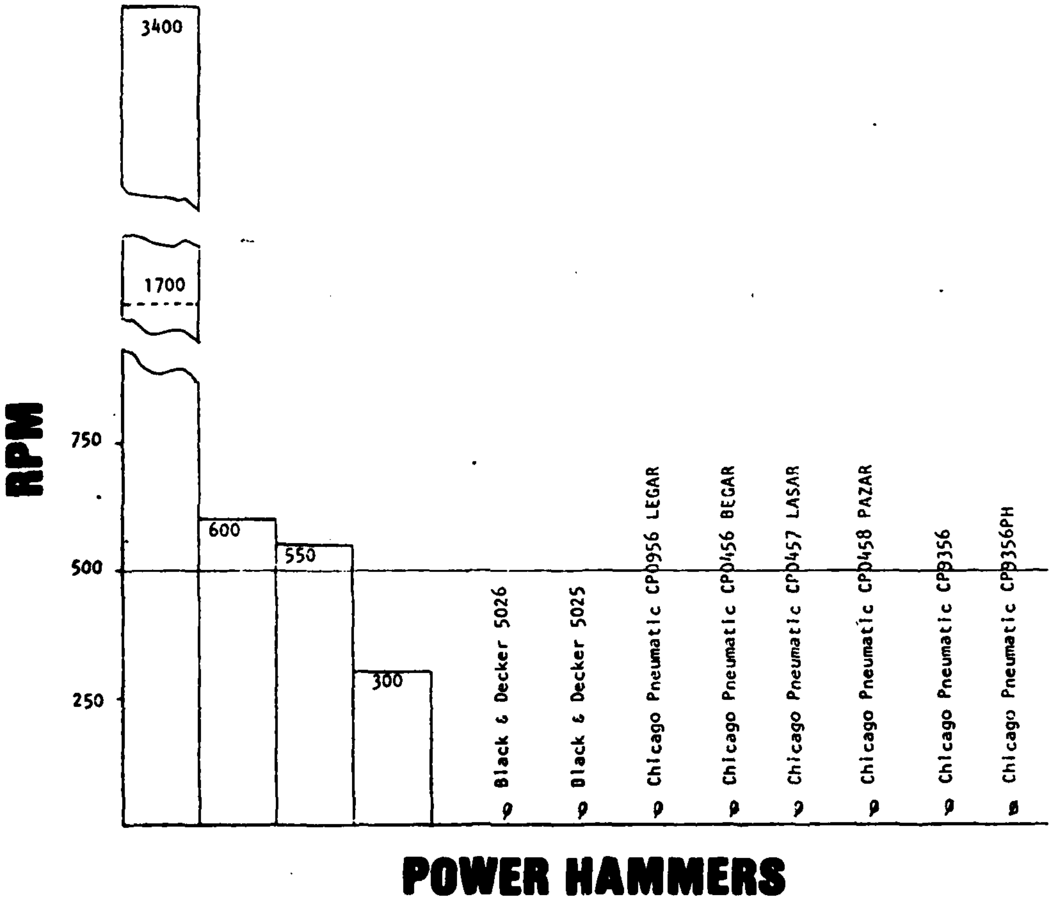


Figure C-20. Rotational Speeds of Power Hammers

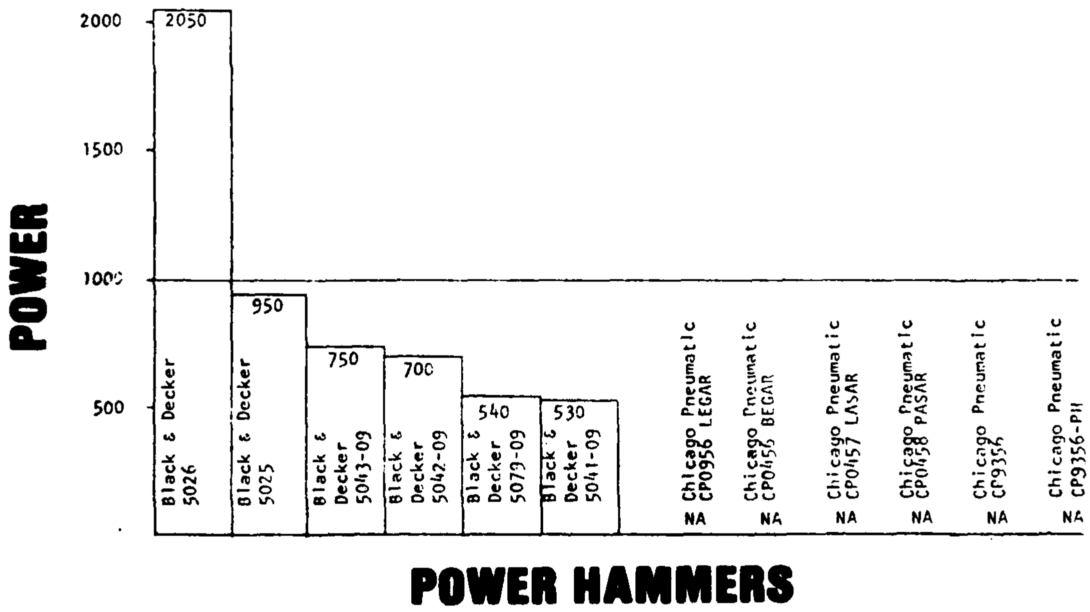


Figure C-21. Relative Power of Power Hammers

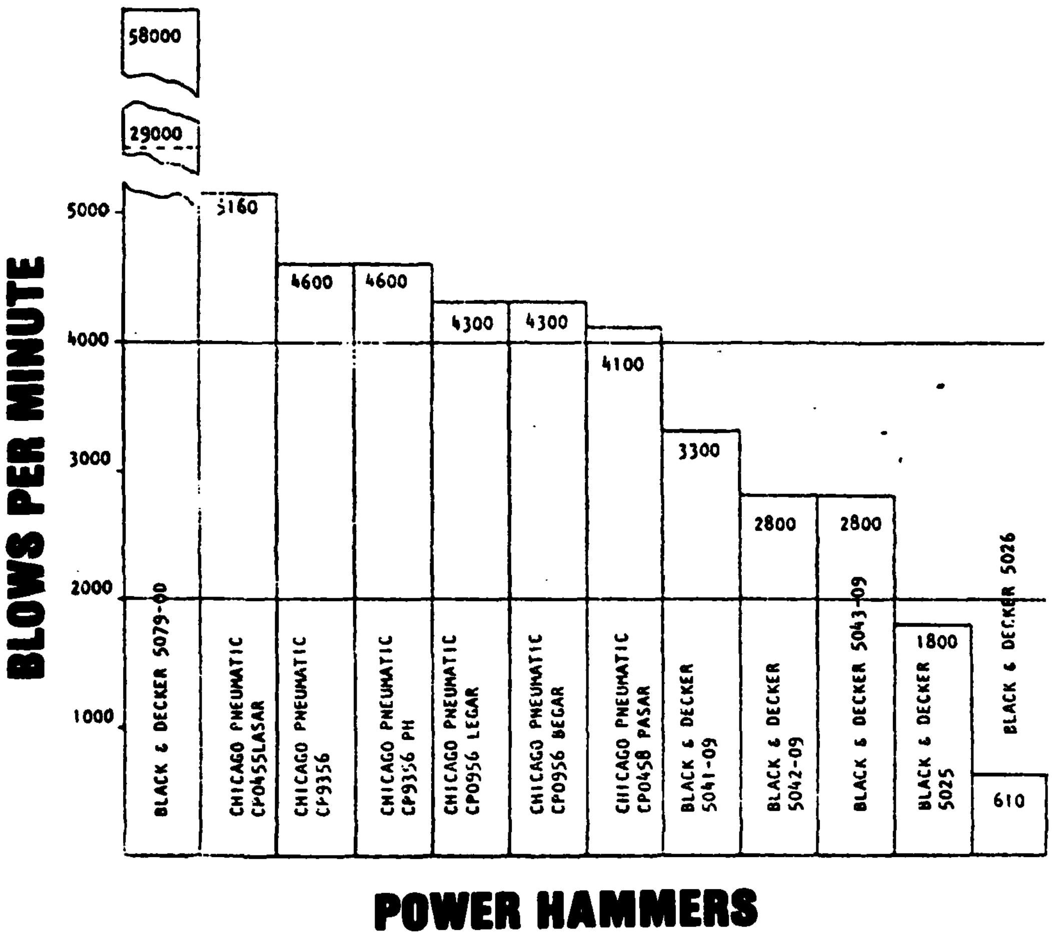


Figure C-22. Frequency of Blows in Power Hammers

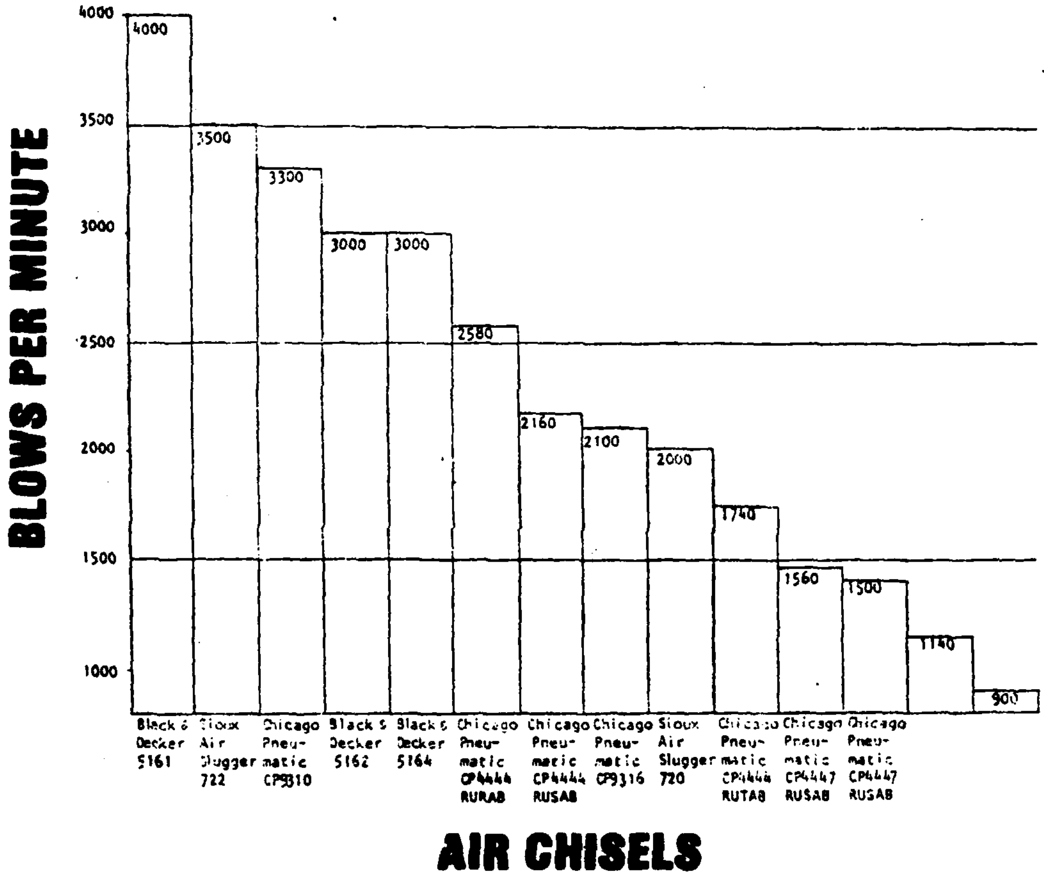


Figure C-23. Frequency of Blows (Air Chisels)

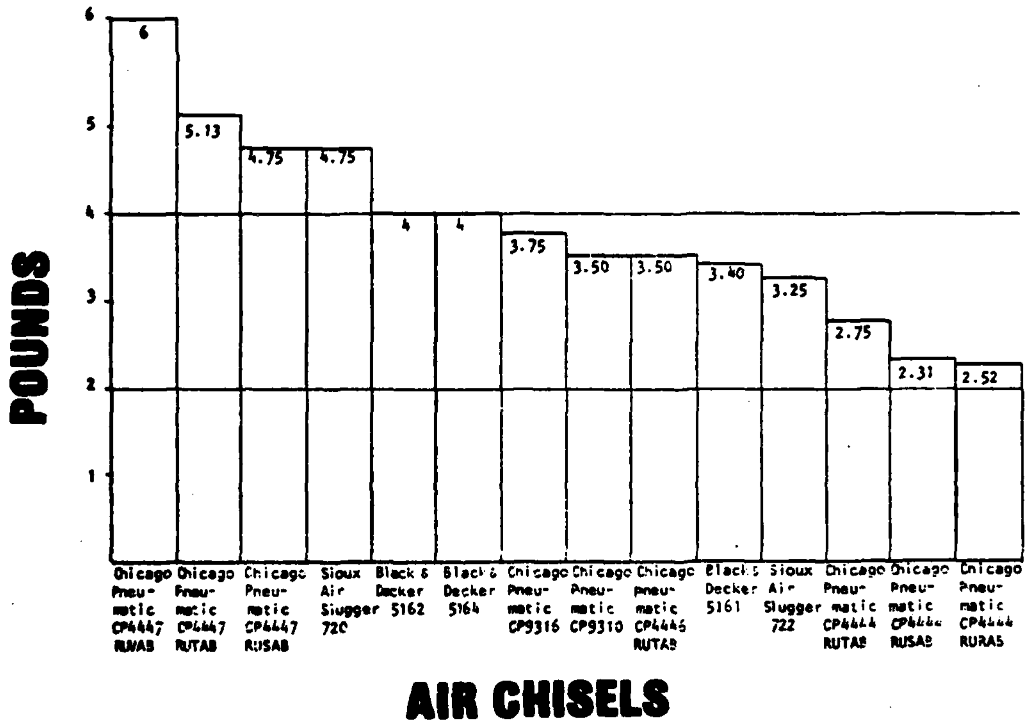


Figure C-24. Weight of Air Chisels

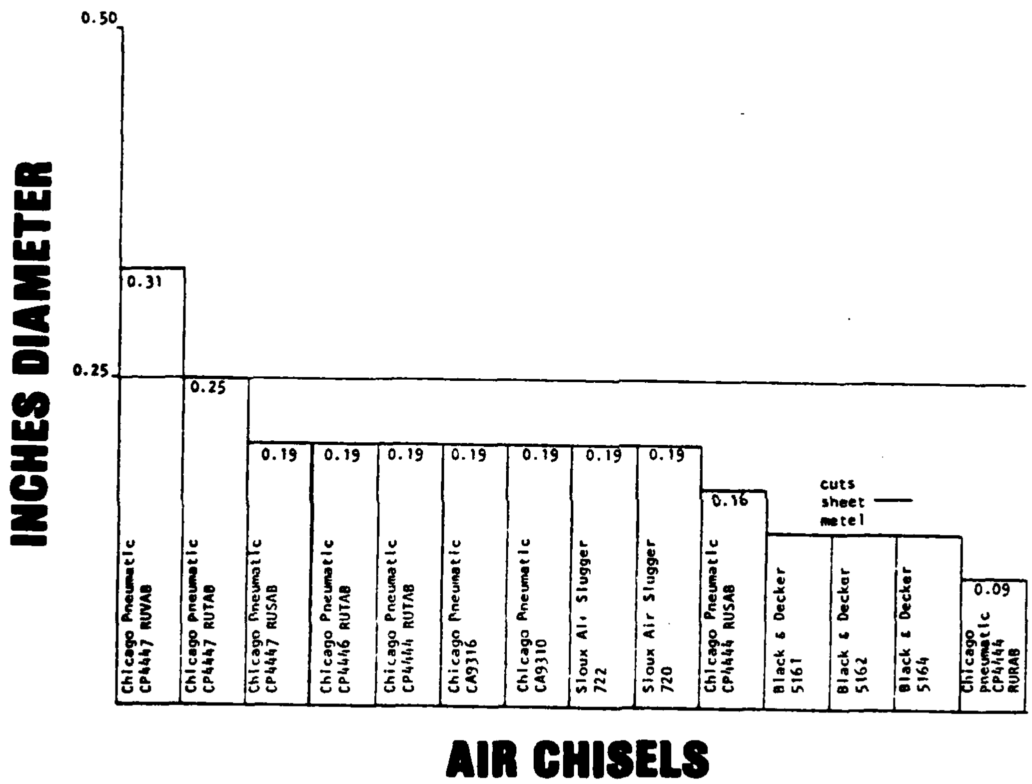


Figure C-25. Relative Material Capacities of Air Chisels (Expressed as Capability to Set Steel Revets)

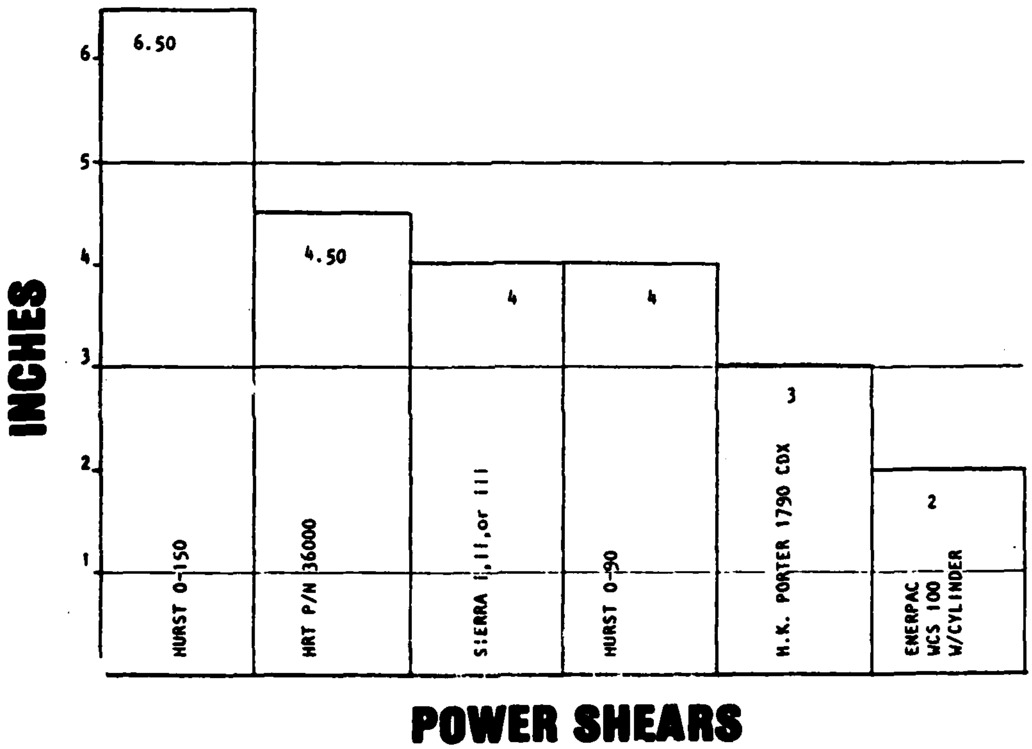


Figure C-26. Opening Capacities of Power Shears

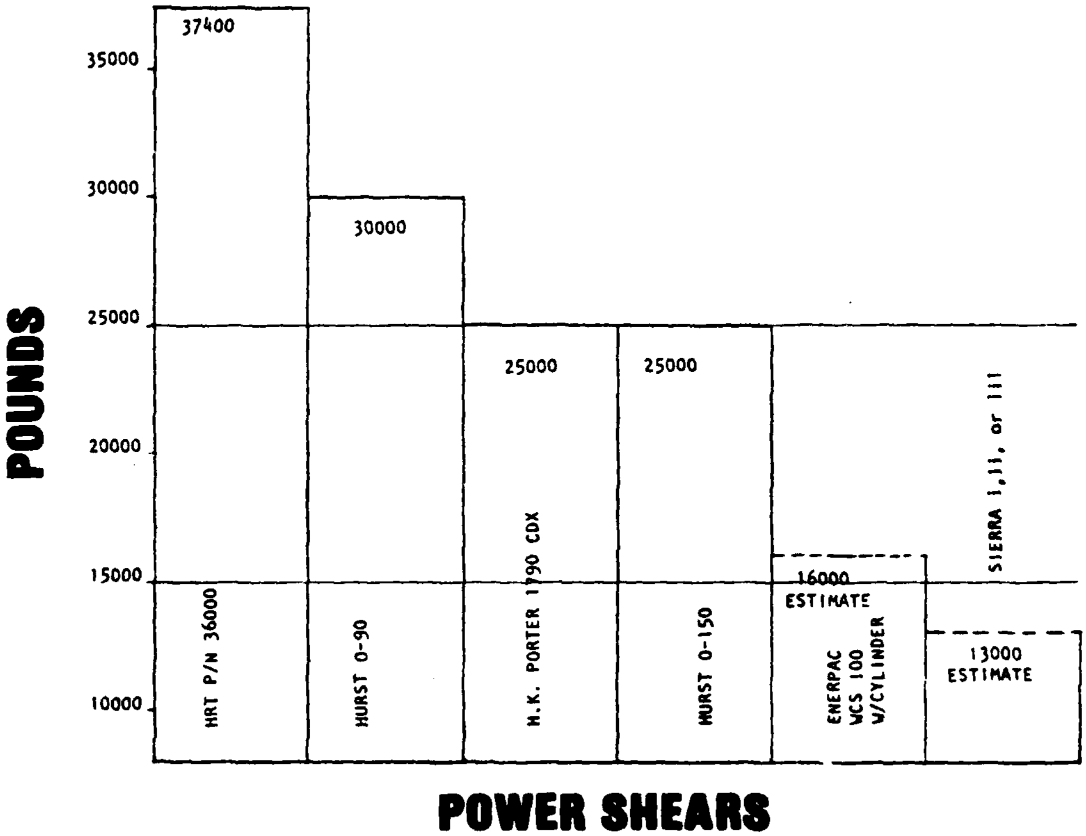


Figure C-27. Cutting Forces of Power Shears

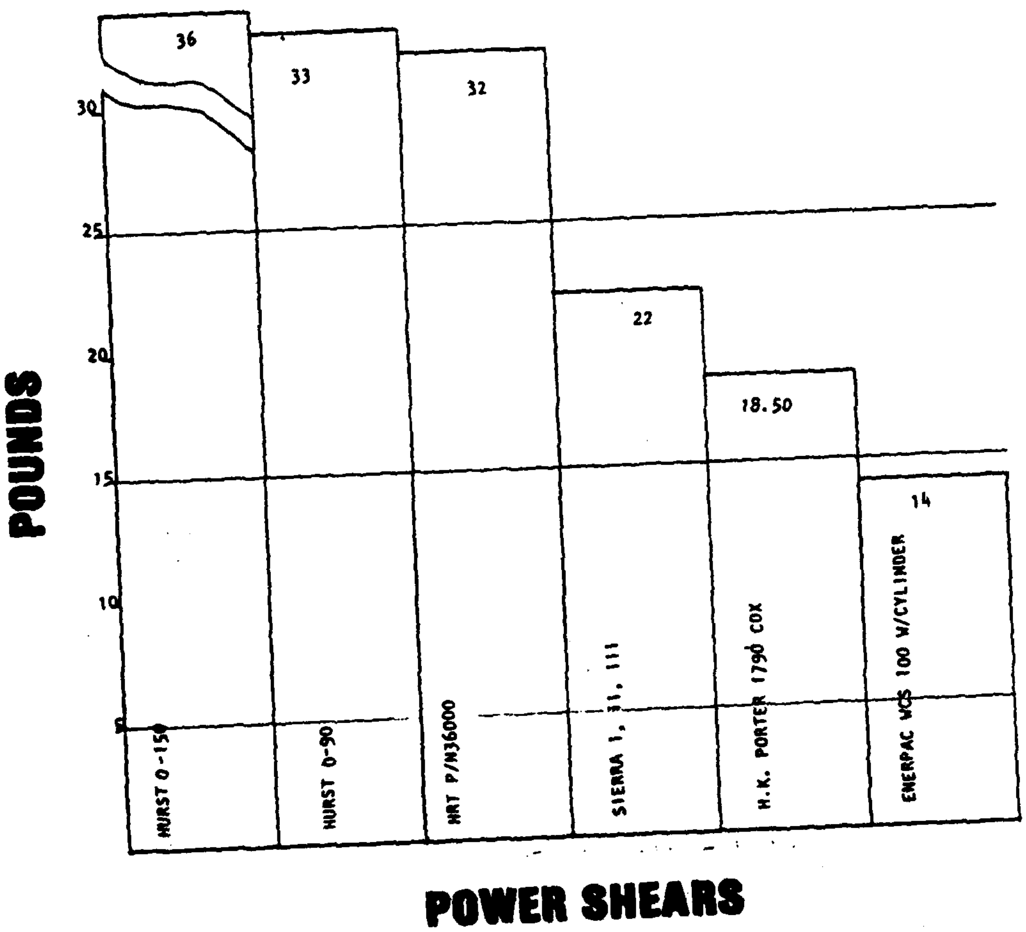


Figure C-28. Weight of Power Shears

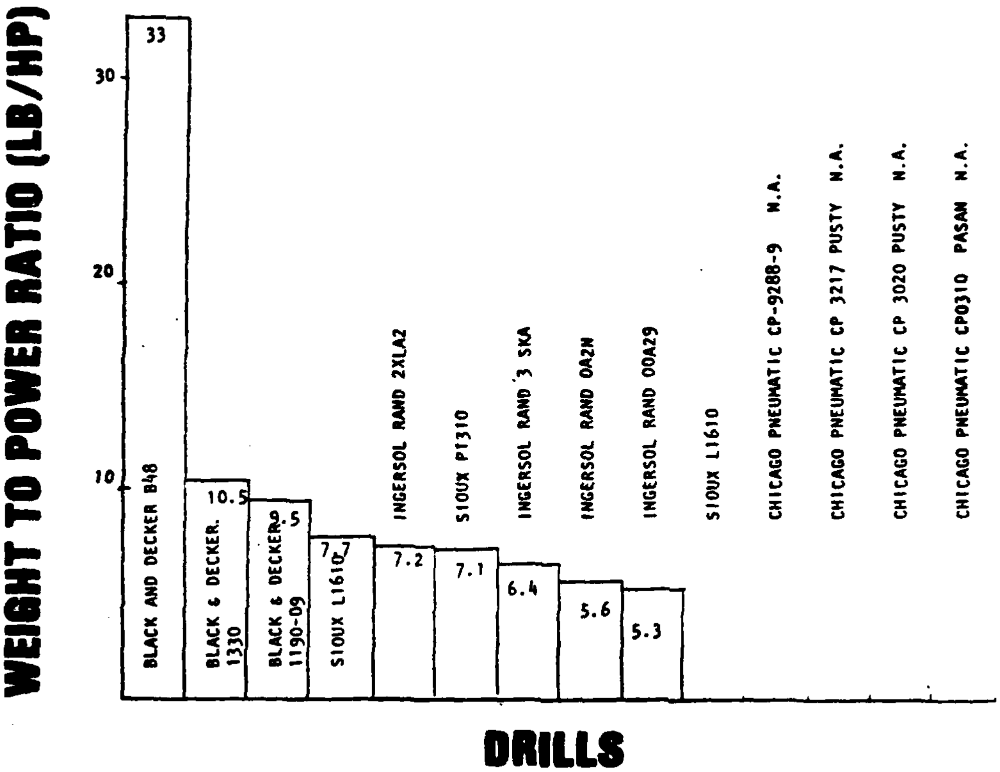


Figure C-29. Drill Weight-to-Horsepower Ratio

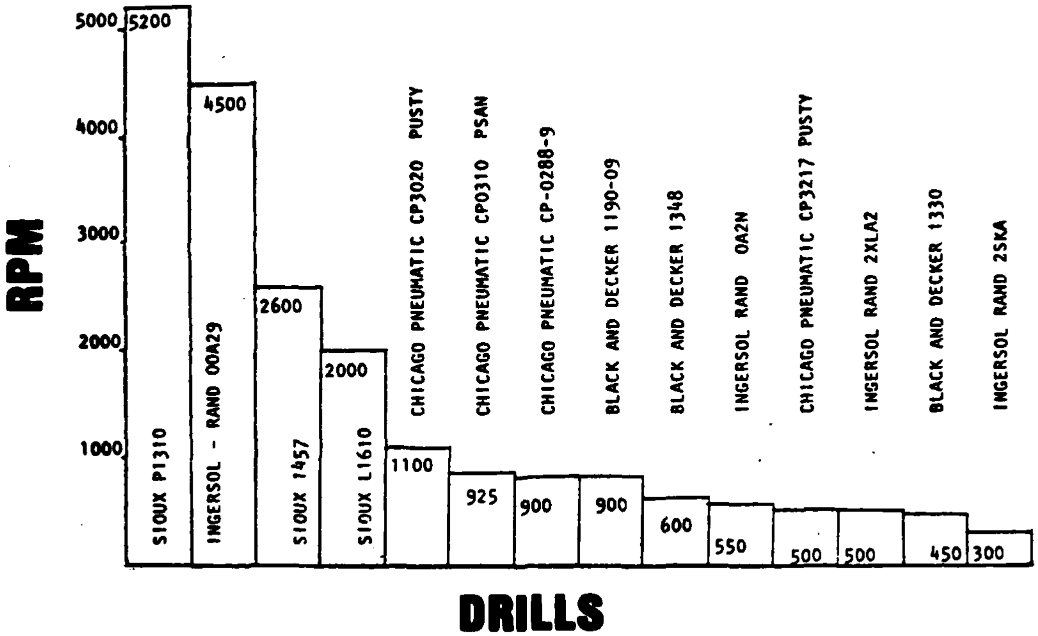


Figure C-30. RPM of Drills

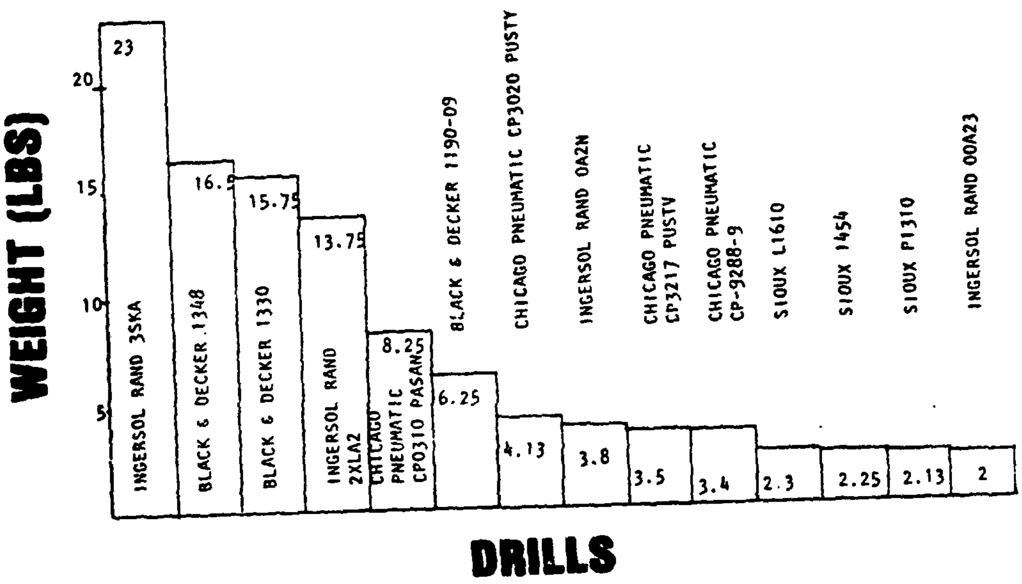
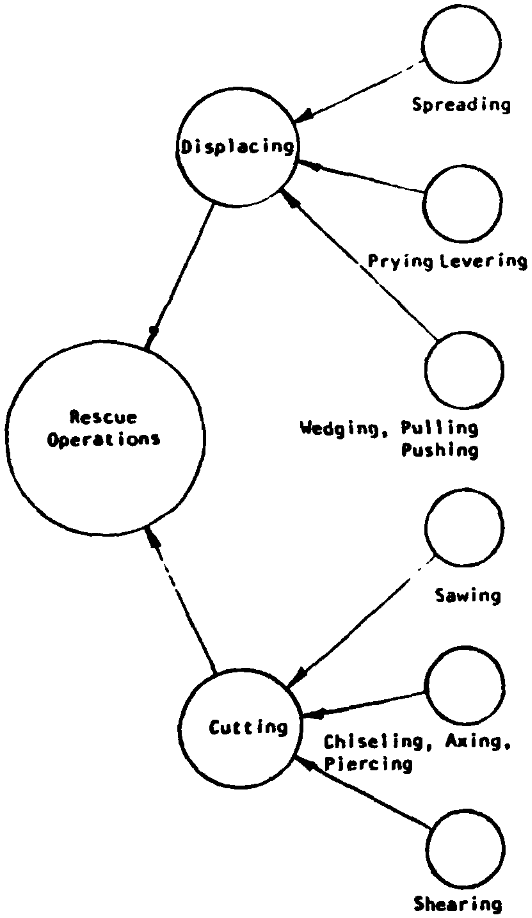


Figure C-31. Weight of Drills

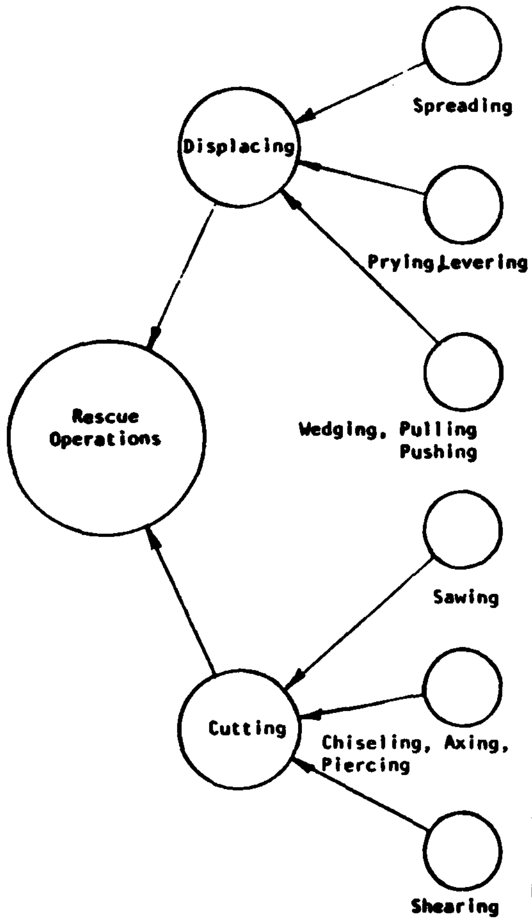
APPENDIX D

GENERAL TOOL COMPARISONS



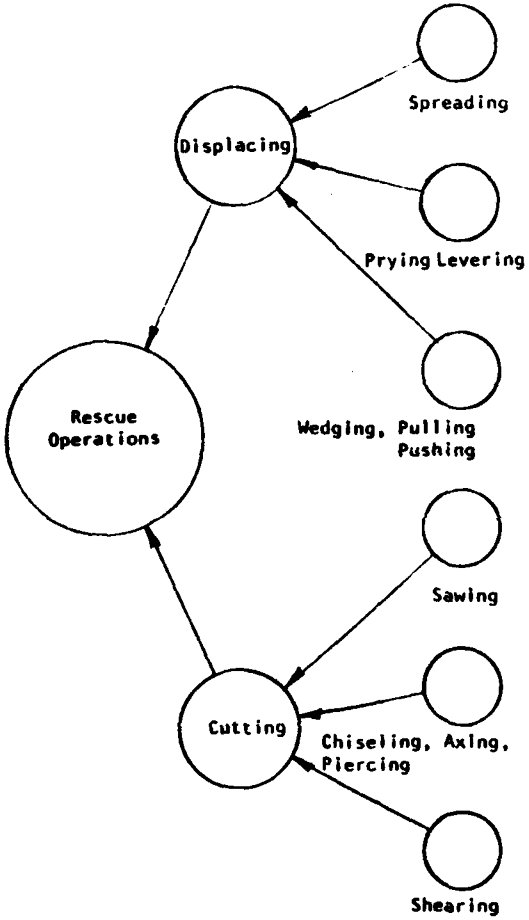
GOOD USE	REQUIRES SECOND TOOL	NOT GOOD CHOICE
	o STARTING HOLE o POSSIBLY SAW CUTS	
CAN OPENER TYPE PRY BAR		
	o STARTING HOLE o SAW CUTS	
X		
X	AXE REQUIRES HAMMER	
		X

Figure D-1. Tool Suitability For Making Man-Sized Hole in Aircraft Skin



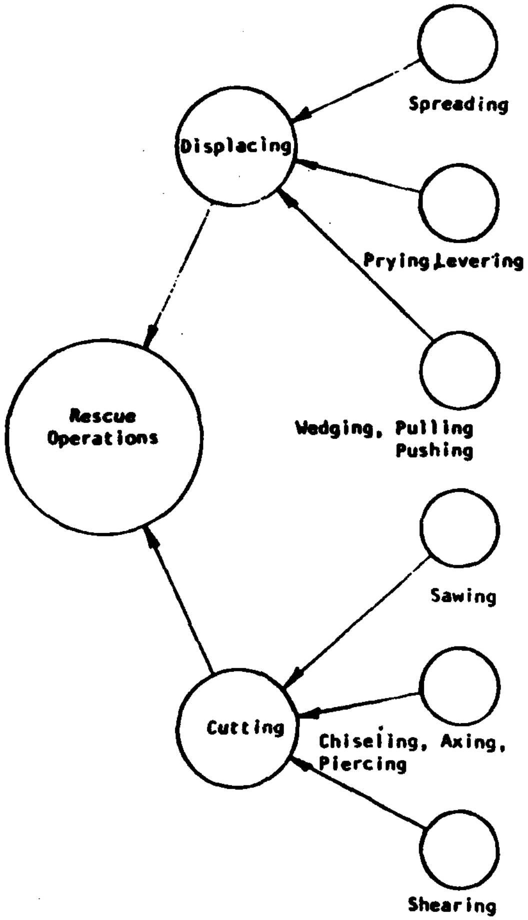
GOOD USE	REQUIRES SECOND TOOL	NOT GOOD CHOICE
	o PURCHASE POINT o DISTORT TO FAILURE	
	PRY BARS o PURCHASE POINT o DISTORT TO FAILURE	
		X
	RIGID SUPPORT	
AXES	o RIGID SUPPORT o LIGHT GAUGE	
X		

Figure D-2. Tool Suitability for Removing Cables, Hoses



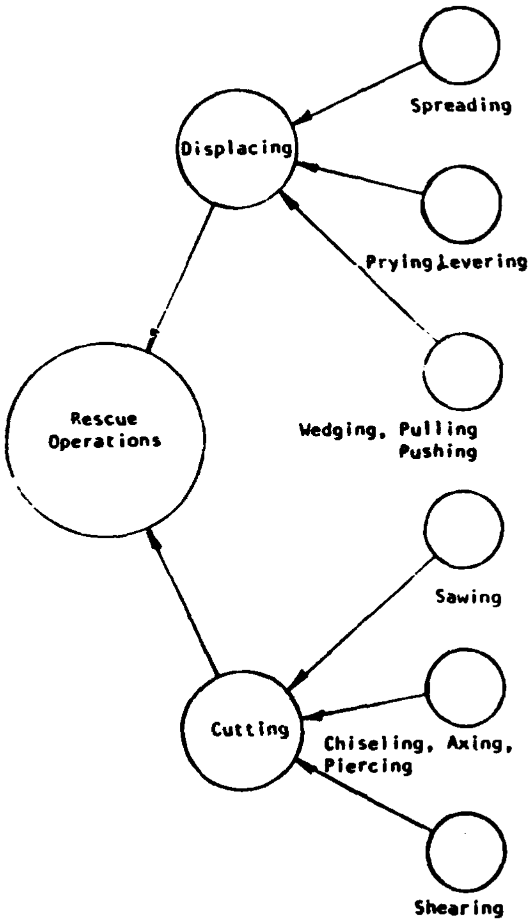
GOOD USE	REQUIRES SECOND TOOL	NOT GOOD COICE
X		
X		
	REQUIRES PURCHASE POINT 45^{o} to 90^{o} AWAY	
		X
	REMOVE LIGHT HINGES FASTNERS USE PRY BAR, SPREADER	AXES
		X

Figure D-3. Tool Suitability For Forcing Doors



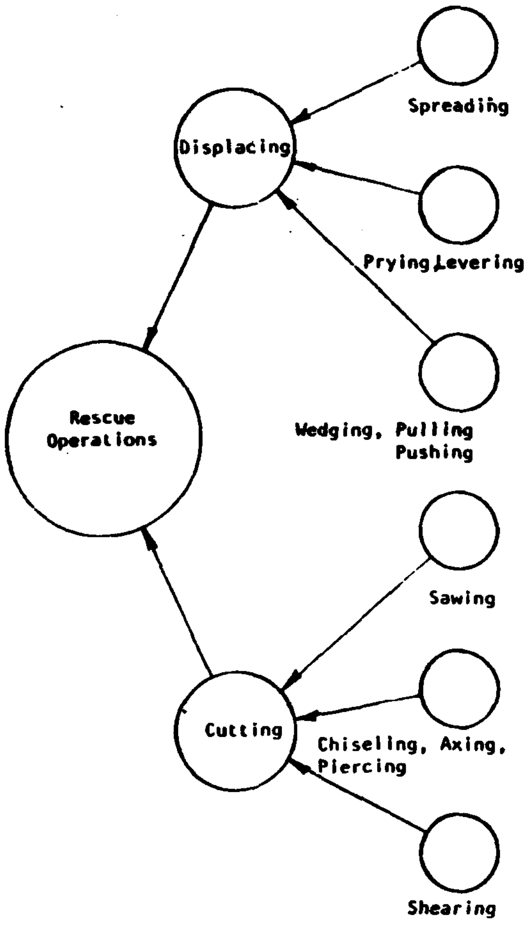
	GOOD USE	REQUIRES SECOND TOOL	NOT GOOD CHOICE
Spreading	X		
Prying,Levering	o LIGHT PARTS o WEAK PARTS		
Wedging, Pulling Pushing	o LIGHT PARTS o PURCHASE POINT REQUIRED		
Sawing	o PANEL LIKE PARTS		
Chiseling, Axing, Piercing	o PANEL LIKE PARTS o VERY LIGHT PARTS		
Shearing	o SMALL DIAMETER PARTS		

Figure D-4. Tool Suitability For Separating Aircraft Parts



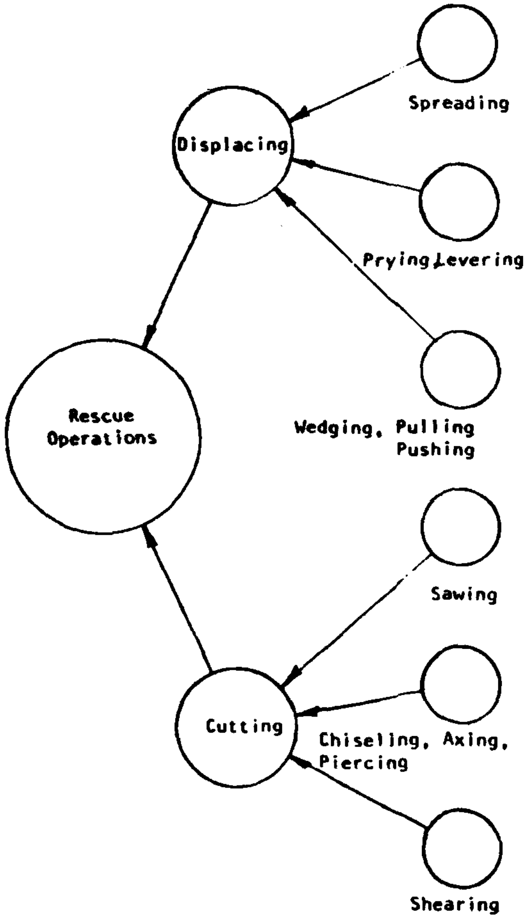
ADVANTAGES		DISADVANTAGES
o GREAT FORCE o LARGE OPENING FROM ONE TOOL o SPEED		o HEAVY o REMOTE POWER o HYDRAULIC FLUID FIRE HAZARD o COST
o NO REMOTE POWER o CAN CUT EFFECTIVLY o CHEAP o LIGHT		o SPARK HAZARD HAMMER AXE CUTTING SLIDE HAMMER o SLOW o LOW POWER
o GREAT FORCE o REACH		o CUMBERSOME o SLOW o MINIMUM REACH
o LIGHT WEIGHT o CUTTING ACTION o PNEUMATIC POWERED AVAILABLE		o DIFFERENT BLADES FOR DIFFERENT MATERIALS o REMOTE POWER (NON PNEUMATIC o BLIND BACK SIDE CUT
o PNEUMATIC POWER o LIGHT o FAST EASY ON LIGHT GAUGE o MODERATE PRICE		o SPARK HAZARD CUTTING STEEL o NO GOOD FOR HEAVY GAUGE
o GREAT FORCE o SPEED		o COST o HEAVY o REMOTE POWER REQUIRED o LIMITED JAW CAPA-CITY o HYDRAULIC FUILD

Figure D-5. Advantages and Disadvantages of Various Rescue Tools



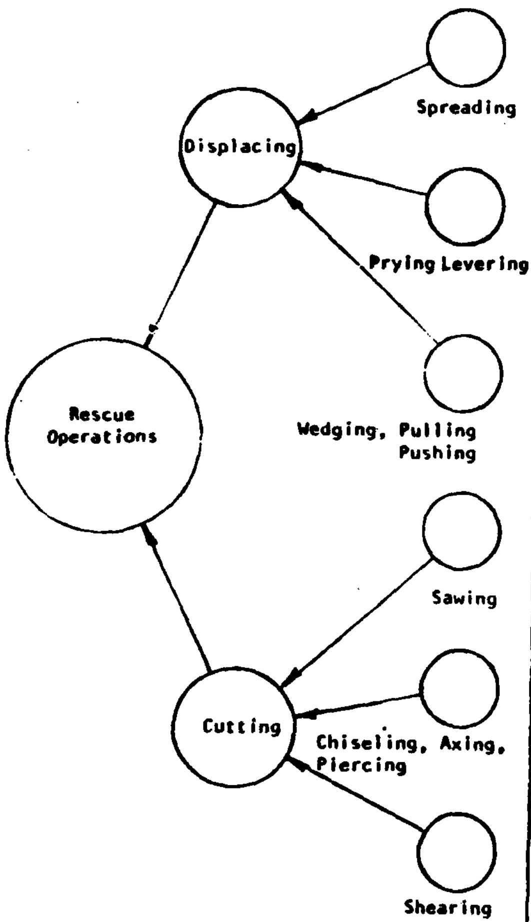
MANUAL	HYDRAULIC	ELECTRIC	PNEUMATIC	GASOLINE	WATER
	PRIME POWER 4 H.P. PUMP FLOW 54 CU IN/MIN at 100 PSI				
TYPICALLY 12"to53" LONG					
ESTIMATE 18" LONG					
	7 to 9 GPM @ 1000 to 2000 PSI	~1500 WATTS 110V	45 CFM @ 85 PSI	376 H.P.	356 GPM 200 PSI
		400 to 2000 WATTS	4 to 7 CFM 90 to 120 PSI UP TO 275 PSI		35 GPM 200 PSI
TYPICALLY 14" to 42" LONG	EXAMPLE PUMP 80 CU IN/MIN GAS or ELECTRIC PRIME POWER		80 to 120 PSI		

Figure D-6. Power Details For Typical Rescue Tools



	MANUAL	HYDRAULIC	ELECTRIC	PNEUMATIC	GASOLINE	WATER
Spreading		X HIGH PRESS-URE ALLOWS HIGH ENERGY /LB				
Prying,Levering	X					
Wedging, Pulling Pushing	X					
Sawing		X	X GENERALLY	X	X MODERATE POWER	X EXCELLENT POWER
Chiseling, Axing, Piercing			X	X		X
Shearing	X ALWAYS AVAILABLE	X		X POSSIBLE TO USE EXTIN-GUSHING AGENT AS POWER GAS		

Figure D-7. Typical Power Sources For Rescue Tools



HEAVY > 25 pounds	MEDIUM ≤ 25 ≥ pounds	LIGHT < 10 pounds
o HURST (32a,28,12) o HRT (26" , 8") o LUKAS (44A)	o ENERPAC (WR15,A92 W/RC 106) o BLACK HAWK	o ENERPAC CW4, WR6
	o SUPER RAM BAR o HOOLIGAN TOOL (i, ii, iii) o FORCIBLE ENTRY BAR o HOLME QUICK-BAR-T	o ZICO (QUICK BAR) (MINI QUICK BAR) o PRY AXE
o C.M. PULLER 3 TON	o C.M.PULLER 1 1/2 TON	o INGERSOL-RAND (SRA 010A1) o BLACK & DECKER (3103-09, 3157-10, 3153-10, 3159-10)
o BLACK & DECKER 3912 o PARTNER (K65,K1200) o HOMELITE (DM50, XL98A) o TARGET QUICKIE (5714612, 5714616)	o BLACK & DECKER 3052 o THOR (6015) o WIDDER (MOT6-20) o ROCKWELL (522-510) o AMFIRE o HOMELITE (DM20) o TARGET (5714608 ELECTRIC	o BLACK & DECKER (5161, 5162, 5164 o SIOUX (720, 722) o CHICAGO PNEUMATIC (CP9316, CP4444, CP4447)
o HURST (0) FRT (P/N 36000)	o SIERRA EXTRACTION (PH 10 to 12) o H.K.PORTER (1790 CDX) o ENERPAC WCS 100 W/CYLINDER	

Figure D-8. Relative Weights of Rescue Tools

(The reverse of this page is blank.)

APPENDIX E

TABLE OF TOOL MANUFACTURERS

TABLE E-1. TOOL MANUFACTURERS

MANUFACTURER	MODELS OR TRADE NAMES	TYPES OF PRODUCTS
A B Partner Fack S-432 20 Moindal Sweden (031)87-07-00	K 65 K 1200	
Ajax Tool Works 10801 Franklin Avenue Franklin Park, Illinois 60131 (312)722-2222		Rescue Air chisels
Amfire Industries, Inc. P.O. Box 24657 Tampa, Florida 33623 (813)884-8424	Water saw Water drill	Circular saw Reciprocating saw Drill Power hammer
The Aro Corporation One Aro Center Bryan, Ohio 43506 (419)636-4242		Air chisel Panel saw
Atlas Safety Equipment Company, Inc. 1 Johnston Avenue Matawon, New Jersey (201)583-6200	Crash Axe 4430 Crash Axe 4530 Crash Axe 4630	Axes
The Black & Decker Manufacturing Company 701 East Joppa Road Department 3865 Townson, Maryland 21204 (301)828-3900	5041-09 5042-09 5026 5025 3912 3052 3103-09 3157-10 3153-10 3159-10 3325 3310 3320 3330 3300 3265 1348 1330 1190-09 5161 5162 5164 5079-09	Circular saws Reciprocating saws Drills Power hammers Routers

TABLE E-1. TOOL MANUFACTURERS (CONTINUED)

MANUFACTURER	MODELS OR TRADE NAMES	TYPES OF PRODUCTS
CM Hoist Division Columbus McKinnon Corp. 5000 Fremont Avenue Tonawanda, New York 14150 (716)696-3200	3 ton CP Puller 1-1/2 ton CM Puller	Come-a-longs
Chicago Pneumatic 608 Country Club Drive Bensenville, Illinois 60106 (312)921-0300	CP 9288-9 CP3217 PUSTU CP3020 PUSTY CP0310 PASAN CP4444 RUSAB CP4444 RUTAB CP4444 RURAB CP4446 RUTAB CP4447 RUVAB CP4447 RUTAB CP4447 RUSAB CP9310 CP9316 CP0956 LEGAR CP0456 BEGAR CP0457 LASAR CP0458 PASAR CP9356 CP9356-PH	Air chisels Power hammers Drill
The Cleveland Twist Drill Company P.O. Box 6656 Cleveland, Ohio 44101		Drill bits Circular saw blades
Dotco/Gardner-Denver Ohio Rte 18E Hicksville, Ohio 43526 (419)542-2221	10L4216 10L4217 10L4218	Panel cutters
Enerpac Bulter, Wisconsin 53007 (414)781-6600	Wedgie WR15 A-92 WR4 WR6 WCS100 JSH121 RCH106	Spreaders Wedges Cylinders Pumps Power shear
Robert G. Evans Company 4332 Clary Boulevard Kansas City, Missouri 64130 (816)923-5040	Target Quickie 5714612 (12/65) 5714616 (14/65) 5714608 (12/45) Electric	Circular saws

TABLE E-1. TOOL MANUFACTURERS (CONTINUED)

MANUFACTURER	MODELS OR TRADE NAMES	TYPES OF PRODUCTS
H. K. Porter, Inc. 74 Foley Street Somerville, Massachusetts 02143 (617)776-8200	1790CDX	Power shears Manual shears
Holmatra Industrial Equipment P.O. Box 33 4940 AA Raamsdoksveer Netherlands	26" 8" P/N 36000	Spreading rescue tools Power shears
Holmes, Ernest Division Dover Corp. 25005 East 43rd Chattanooga, Tennessee 37407 (617)867-2142	K-Bar-T	Slide hammer Pry bar
Homelite Textron 14401 Carowinds Boulevard Charlotte, North Carolina 28217 (704)588-3200	DM50 XL98A DM20	Circular saws
Hurst Performance, Inc. Safety Products Division 1957 Pioneer Road Huntington Valley, Pennsylvania 19006 (215)672-1700	32A 28 12 0-90 0-150	Spreading rescue tools Power shears
Ingersoll-Rand 28 Kennedy Boulevard East Brunswick, New Jersey 08816 (201)846-5400	SRA010A1 2XLA2 3SKA 0A2N	Reciprocating saw Drills
Kett Tool Company 5053 Madison Road Cincinnati, Ohio 45227 (513)271-0333	KS21AM KS23AM KS25AM	Panel saws
Lukas 5203 Thatcher Road Downers Grove, Illinois 60515 (312)963-6575	44A 22A	Spreading rescue tool Power shears

TABLE E-1. TOOL MANUFACTURERS (CONTINUED)

MANUFACTURER	MODELS OR TRADE NAMES	TYPES OF PRODUCTS
Paratech Incorporated 1025 Lambrecht Road Frankfort, Illinois 60423 (815)469-3911	Maxiforce Hooligan Tool i,ii, iii Pry axe Forcible entry bar Super Rambar	Air list bags Pry bars Importer for HRT Tools
Rockwell International Power Tool Division 400 North Lexington Avenue Pittsburgh, Pennsylvania 15208 (412)243-3500	52Z-510	Reciprocating saws
Sierra Fire Equipment Co. 3804 S. Broadway Place Los Angeles, California 90037 (213)232-3131	GlasAx Sierra I Sierra II Sierra III	Axes Power shears
Sioux Tools, Inc. 2901 Floyd Boulevard Sioux City, Iowa 51102 (712)252-0525	3P1460 1980 1981 1983 1984 21610 P1310 1454 Air Slugger 720 Air Slugger 722	Circular saws Panel saws Routers Saw blades
The Stanley Works 13770 Southeast Ambler Road Clackamas, Oregon (503)659-5660	6008 6023	Circular saws
Thor Power Tool Co. 175 North State Street Aurora, Illinois 60507 (312)898-8000	601S	Circular saws
Widder Corporation Great Hill Road Naugatuck, Connecticut 06770 (203)723-0901	MOT 620 AST 750 18 800	Reciprocating saws
Ziamatic Corporation 10 West College Avenue P.O. Box 337 Yardley Industrial Park Yardley, Pennsylvania 19067 (215)493-3618	Quik Bar Mini Quik Bar Quik K-Bar-T Quik Cut	Air chisel Pry bars

(The reverse of this page is blank.)

ATE
LME